BUILDERS' GUIDE

to Energy Efficiency in New Housing

THIRD EDITION

Canadian
Home Builders
Association

Association
canadienne
des constructeurs
d'habitations

Ontario Ministry of Energy

May, 1987
Third Edition

Further copies of this Guide may be obtained at the
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FOREWORD TO THE FIRST EDITION

The Canadian Home Builders Association (CHBA) and the Ontario Ministry of Energy, through their joint sponsorship of this Builders' Guide, have shown a fine example of private and public sector cooperation to achieve a common goal – reduced energy consumption.

CHBA took the responsibility for coordination and quality of the Guide development, ably assisted on the Steering Committee by the Ontario Ministry of Housing, the Ontario Ministry of Consumer & Commercial Relations, Ontario Hydro, the Ontario Council of CHBA, and, of course, financially and technically, by the Ontario Ministry of Energy.

The consultant study team of the IBI Group, Scanada Consultants Ltd. and Hooper and Angus Associates Ltd. has applied its knowledge and analytical capabilities in site planning and architectural design, building science, construction, mechanical equipment and marketing.

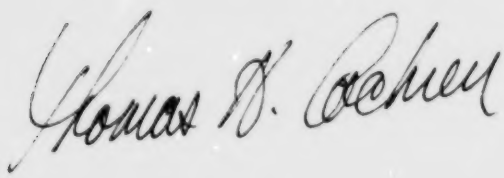
The Guide's contents and presentation are intended to emphasize day-to-day knowledge which will help the Canadian builder to achieve practical results in the field of energy conservation.

Hugh L. Molland
Chairman, CHBA/Ontario Ministry of Energy Steering Committee

February 1980

FORWORD TO THE THIRD EDITION

The Canadian Home Builders' Association and the Ontario Ministry of Energy are pleased to present this updated edition of the Builders' Guide. The popularity of the first two editions indicates the usefulness of the Guide. This third edition was prepared by REIC Ltd., and reflects recent developments in the field of energy efficient house construction — specifically those stemming from the R-2000 Program.



Tom Cochren
President, Ontario Home Builders'Association
May, 1987

Preface

Canadian home builders and home owners can play an important role in conserving our energy supplies. The present dwelling stock consists of about 8.5 million units. During the 1980's this will increase by some 25%. The manner in which builders design and construct these units will have an important effect on the national consumption of home energy.

Most builders find their time is fully occupied in dealing with day-to-day activities of financing, selection and buying of lots, construction, and sales. Little time is left for actively researching the building science options and technology to improve energy efficiency. Although considerable literature is available on the theory of energy use and conservation in buildings, there is no comprehensive guide for Canadian builders that offers practical suggestions related to market conditions.

The purpose of this guide is to give the average Canadian builder practical information and guidance in the area of energy conservation in new housing. It offers useful suggestions for planning, designing and building a more energy efficient home. Builders can use these suggestions at their own discretion to improve the quality of their dwellings and provide cost saving benefits for the buyers.

The guide provides advice on energy efficient techniques suitable for low-rise housing (singles, semis and duplexes, row housing, and walk-up three-storey apartments), which is, and is expected to remain, the most common form of housing built in Canada.

Most building codes across Canada already provide for a relatively high level of energy efficiency, representing significantly higher energy conservation over code requirements of the mid 70's and earlier. For purposes of this guide provisions of the 1983 Ontario Building Code were taken as the basis upon which to develop and evaluate improvements. Such improvements beyond code standards can be shown to be desirable under certain conditions because energy prices are continuing to rise and future supplies are in question.

The Guide emphasizes **what** to do, **how** to do it (indicating special construction procedures or considerations where warranted), and **why** it is important. Detailed background information and building science theory have been kept to a minimum; there are excellent publications available for those builders interested, and the Canadian Home Builders' Association has prepared a bibliography as part of the development of the Guide.

The Guide is organized in ten sections to provide clear recommendations with a minimum of cross referencing.

Note:
The Guide makes reference to CMHC Builders' Bulletins currently in use. These are updated from time to time. Users of the Guide should ensure that they are referring to the latest version of these Bulletins, by checking with local CMHC offices.

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This section provides a brief background to the use of energy for housing in Ontario. It notes the proportion of energy use devoted to housing, reviews trends in energy sources for new housing, illustrates energy cost trends and projections and outlines possible energy savings in new housing.

1.1 Energy Trends

Residential energy needs in Ontario account for 20% of total energy use (see Figures 1.1 and 1.2). Thanks mostly to a greater public awareness and to technological advances in the building industry, Ontario's need for energy in the residential sector is expected to grow only moderately in the next fifteen years. Predictions indicate that, by the year 2000, overall energy efficiency can be expected to improve by 20% over today's standards.

Changes in the way that energy is used will lead to lower energy requirements in relation to economic activity. Energy needs are expected to grow by only one-third as much as the projected growth of the economy. The greatest improvements will likely be in home heating efficiency. By the year 2000 the average home may be run on 25 per cent less energy.

1.1.1 Energy Price Trends & Fuel Sources for Residential Energy Use

The prices of major energy sources are expected to be relatively stable in the next decade or so. It is quite possible that oil and natural gas prices could improve in the 1990s as supply and demand balance out. Electricity prices in Ontario are expected to keep pace with inflation.

Fuel Shares Predictions—Residential

oil	down	46%
electricity	up	18%
gas	down	5% (600,000 more homes with more efficient furnaces)
wood, solar & other	up	41%

1.2 Residential Energy Use

In the province of Ontario by the year 2000, there will be 13 per cent more people and nearly a million more houses and apartments. Yet the total amount of energy used in all the homes in the province, will be less at the turn of the century than it was in 1984. Home heating will provide the largest area of energy savings.

The construction of low energy R-2000 homes and the retro-fitting of older homes with sealing, insulation and high-efficiency heating systems will also account for greater savings. The new homes will tend to be smaller (because of rising housing costs and smaller family size), and will need less heat. The move to apartments and town houses will continue as will the trend toward smaller homes.

Improvements in heating equipment, structural improvements, and more energy-efficient household appliances will help keep energy demands at manageable levels. In the year 2000 the average Ontario home could use one-quarter less energy than its equivalent today.

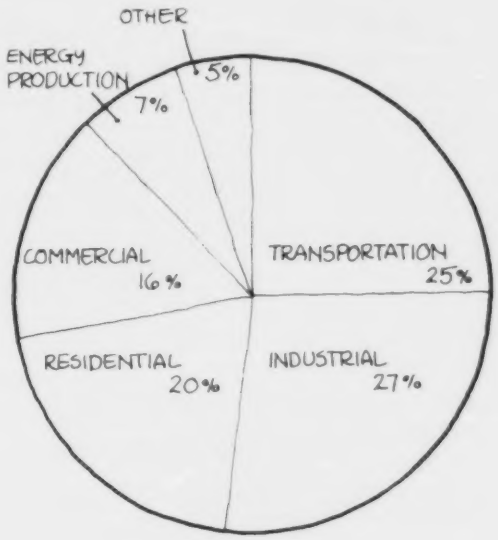

FIGURE 1·1 ENERGY USE BY ACTIVITY SECTOR

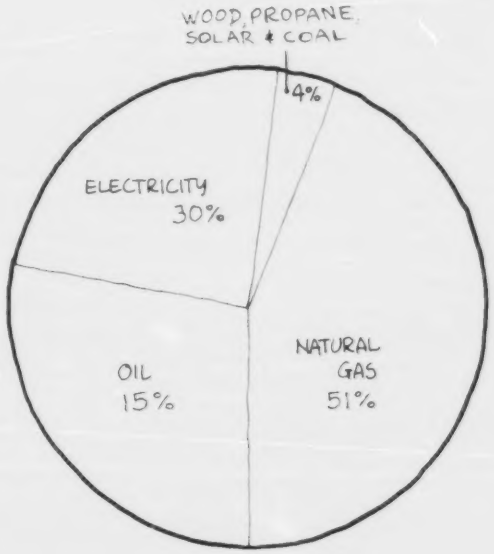

FIGURE 1·2 ENERGY SOURCES FOR THE RESIDENTIAL SECTOR

1.2.1 Trends in Housing Stock

In future the number of new homes built will decrease , simply because the rate of population growth is declining. By the year 2000 a quarter of Ontario's homes will have been built since 1984 and the majority of homes will date from before 1973. As a result, improvements in older homes will be as important as better new house design and construction.

The trend toward apartments and town houses will help to cut Ontario's home energy needs by some 3 per cent by 2000. The smaller floor area and fewer exterior walls in townhouses and apartments require, respectively, half as much and less than one third as much energy for heating.

The smaller home/town house/apartment shift results from economics and demographics. Smaller families, low birth rates, single-parent families, a growing number of seniors and those attracted to low-maintenance apartment living, and the high cost of urban land will all contribute to the move away from the single family home. The proportion of single detached houses in the total housing stock is projected to fall from 57 to 53 per cent.

1.2.2 Structural Improvements in New Housing

Heating needs will account for the area of most dramatic savings in energy use in the home. Approximately two-thirds of the energy used in homes is for keeping the interior space warm. The other one-third is for water heating, cooling and appliances. Heating needs can be cut in two principal ways: by improvements to the building structure and by better heating systems.

Regardless of the source of energy, many opportunities exist for increasing energy efficiency in new housing by building beyond the requirements of current building codes. Canada's R-2000 energy efficient house has won much attention and praise internationally. It represents the best in energy saving technology to date, and will continue to improve with building technology so that by the year 2000, total heating costs in a new home should be up to 90 per cent less than they are today.

Here are the main differences between a conventional house and the R-2000 house.

- insulation — two times the amount required by the Standard Building Code
- air tight construction to reduce unwanted air leakage
- mechanically-controlled ventilation to ensure a continuous supply of fresh air
- high efficiency heating appliances
- windows — double or triple glazed
  — largest window area facing south to collect maximum solar heat

1.3 Retrofitting Older Homes

If new homes can expect to save a maximum of 40 per cent, older detached homes should be able to save an average of 20 per cent on heating bills. Renovations which include insulation, air sealing, or low-cost measures such as caulking, weatherstripping, and sealing cracks and gaps can amount to substantial savings.

1.4 Improvements to Heating Systems

There will be a dramatic improvement in existing energy conversion technologies. The condensing natural gas furnace is an example. It can produce the same usable heat as a conventional furnace with one-third less fuel by condensing the exhaust gases to recover heat otherwise wasted. Heating systems in general and in particular the high efficiency gas furnace have proven extremely economical. Electric heat seems to be an attractive system to many people and may capture as much as 23 per cent of the market during the next 15 years.

1.5 Appliances

Other savings will be made on home appliances, air conditioning and water heating. While the average number of appliances per household is likely to increase, new technologies will result in improved efficiencies. For example, an average increase of 15 per cent is expected in the efficiency rate of most appliances.

1.6 Consumer Benefits

Increasing energy efficiency will reduce annual home operating costs. If these savings are considered as a reduction in mortgage payments, then it is a simple matter to determine what extra home purchase price could be spent on energy-saving improvements with no increase in cost to the home-owner.

In Toronto, a house with a 40% reduction in energy consumption would justify a selling price which would be about $2,300.00 higher than one built to the minimum Ontario Building Code requirements. This is because energy savings in the first year of operation would off-set the increase in mortgage principal and interest payments[1]. In the case of the R-2000 house, yearly heating costs could be as low as $200/year for a small house or $450/year for 3000 square feet.

This example represents today's fuel prices. Energy costs could continue to rise or may remain the same. However, mortgage payments are relatively stable, so the benefits of energy improvements will increase with time. In the above example the savings in energy costs will exceed the mortgage payments on the extra purchase price by larger and larger amounts in future years.

[1]Example is based on a two-storey house with an above-grade floor area of 147m^2, having a mortgage with a 25 year amortization period and an interest rate of 11% to 12% and natural gas costing 22¢ per cubic metre.

Because energy price increases have exceeded the inflation rate in recent years and are estimated to continue to do so, the home purchase price premium for energy efficient features can be a sound investment, paying short and long term dividends. Builders who provide and promote these features could have a definite sales advantage. As the buyer's understanding of the importance of energy conservation grows, many future purchasers may insist on these features. Effective promotion and consumer awareness of the benefits of an energy efficient home will have the greatest effect on new home sales. The growing prospects of future availability problems will increase buyer concern beyond just ensuring that higher first costs are offset by later energy savings. Energy efficiency has become an important consumer consideration.

1.7 Old and New Home Energy Needs

By the year 2000, it is estimated that an average home will use three-quarters of the energy that it used in 1984. This means that the province's total home energy requirements will be lower in future than at present. Improved building structures and more efficient heating systems will be responsible for a 30 per cent heat energy saving.

We are likely to have more houses and more appliances (i.e., greater energy needs) by the year 2000. Given the energy that will be saved as a result of public awareness and new technology, our total home energy needs should be smaller than they are today.

Section 2
Energy Awareness in the Design of the Home

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This section serves an an introduction to the various factors affecting energy use in housing. The section provides background information on heat losses and gains, and an overview of the factors affecting the comfort levels of the homeowner. The effects of housing form, internal layout, siting and landscaping on heat loss are addressed. Finally, an introduction is also provided to the means of measuring the costs and benefits of energy conservation features.

2.1 Heat Loss and Conservation

2.1.1 The Energy Balance

A dwelling unit is usually in a state of balance regarding energy — the heat gains equal the heat losses. When this balance does not exist the temperature either rises or falls until a new balance is reached.

Figure 2.1 shows the energy balance for a typical modern house on a cold winter day. Note that only 83% of the heat input comes from the heating system. Over the entire heating season, the heating system contributes an even lower percentage of the total heat requirement. This is because the total heating requirement varies with outdoor temperatures while some heat sources remain constant or even increase. The heat available from people, appliances, lighting, and water heating is constant throughout the year and solar heat gains are variable. In spring or fall, these other sources contribute a larger portion of the total heating requirement. Figure 2.2 is a simplified illustration of the interrelationship between heat gains and heat losses. It shows that in the early fall and late spring the heating system may not have to operate at all because all heat losses are made up by these other sources.

For a typical Southern Ontario house insulated to Ontario Building Code requirements, the total purchased heat (shaded area in Figure 2.2) might be about 65% of the total heating requirements over the heating season. If the same house were placed in a colder climate with the same amount of sunshine the total heat losses would increase. This increase would have to be made up by longer operation of the heating system. Thus the percentage contribution of the heating system would increase.

Conversely, if the heat losses were to be reduced by, for example, adding more insulation, the heating system's contribution would be reduced. This is illustrated in Figure 2.3. Note that it is reduced in two ways. Not only is the requirement for heat reduced, but also, the length of the actual heating season is reduced. Thus the seasonal saving from energy conservation measures will be a somewhat higher percentage than that calculated on a steady state, point-in-time basis.

2.1.2 How Heat is Lost from the Dwelling

Heat flows from warm to cold. All of the heat that is put into a building is eventually lost to the outdoors. We cannot stop this loss. All we can do is to slow down the rate at which the heat is flowing.

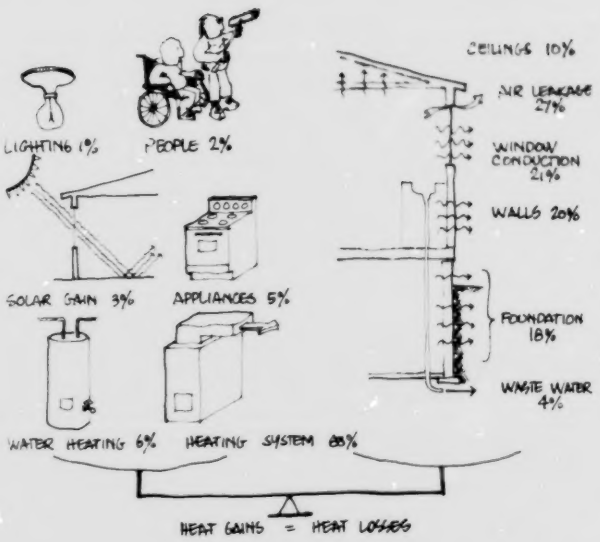


FIGURE 2.1 ENERGY BALANCE ON A COLD WINTER DAY FOR A TYPICAL HOUSE INSULATED TO ONTARIO BUILDING CODE REQUIREMENTS

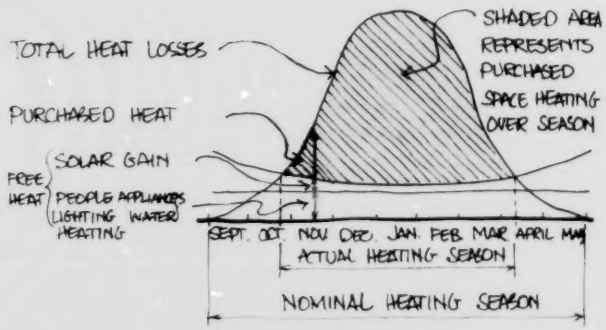

TOTAL HEAT LOSSES
PURCHASED HEAT
SOLAR GAIN
FREE HEAT
PEOPLE APPLIANCES LIGHTING WATER HEATING
SHADED AREA REPRESENTS PURCHASED SPACE HEATING OVER SEASON
SEPT. OCT. NOV DEC. JAN. FEB. MAR APRIL MAY
ACTUAL HEATING SEASON
NOMINAL HEATING SEASON

FIGURE 2.2 HEAT GAINS AND LOSSES OVER THE HEATING SEASON

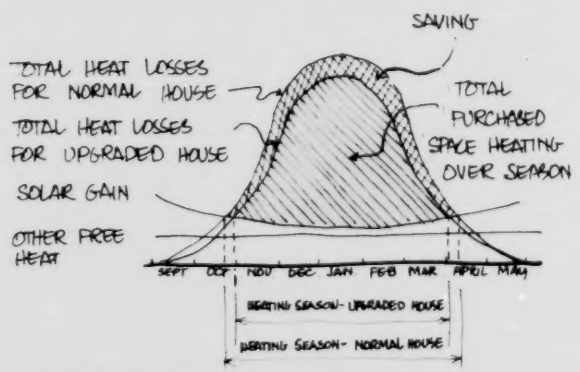

SAVING
TOTAL HEAT LOSSES FOR NORMAL HOUSE
TOTAL HEAT LOSSES FOR UPGRADED HOUSE
SOLAR GAIN
OTHER FREE HEAT
TOTAL PURCHASED SPACE HEATING OVER SEASON
SEPT OCT NOV DEC JAN FEB MAR APRIL MAY
HEATING SEASON- UPGRADED HOUSE
HEATING SEASON- NORMAL HOUSE

FIGURE 2.3 HEAT GAINS AND LOSSES FOR AN UPGRADED HOUSE

Heat Transfer

Heat is transferred through three distinct functions. These are illustrated in practical application in Figure 2.4.

The **conduction** of heat refers to heat flows through a solid material due to molecular agitation.

Heat **convection** describes the transfer of heat which occurs as a liquid or gas (air) flows over a solid material.

Radiation is the transfer of heat through space by electromagnetic waves. The sunshine and a wood stove would serve as typical examples.

The rate of heat flow through the envelope of a building is influenced by:

- the **area** of the material or assembly.
- the **resistance** to heat flow provided by the materials or assembly.
- the **temperature difference** between the outside and inside of the house envelope.

By understanding the relationship of area, resistance and temperature difference, we can analyse the relative contribution of parts of the envelope to total heat loss. Figure 2.5 illustrates the heat losses of ceilings, windows, walls, and foundations for a typical Ontario house. For example, roofs are not that large a source of heat loss — they generally have a high insulation value (in relative terms), and do not represent one of the larger surface areas of the house. On the other hand, foundations are a major proportion of the heat loss of the average house. Insulation levels are generally low, the area is large, and although the surrounding soil affects the temperature difference between the interior and exterior, there is still a large portion of the foundation exposed to outside air and to frozen soil conditions.

As Figure 2.5 illustrates, heat loss from the house also occurs as part of the ongoing leakage of cold air into the building and heated air out of the building. In the vast majority of housing air leakage accounts for the largest percentage of the total house heat loss. A major emphasis of energy efficient construction is on techniques which result in a dramatic decrease in the rate of air leakage through the house envelope. This is discussed in Section 3.

How Insulation Works

All three heat loss mechanisms — conduction, convection, and radiation — take place, for example, in an empty stud space of an exterior wall:

1. Although the air in the space is a poor conductor of heat, a small amount of heat is transferred by conduction through the air.

2. The air in contact with the warm interior surface is heated and becomes lighter than the rest of the air in the space. It rises and moves across to the cold exterior surface where it is cooled, i.e., gives up the heat it had gained. This makes it heavier and thus it falls and moves across to the warm interior surface where the process begins again. A much larger amount of heat is transferred by convection than by conduction.

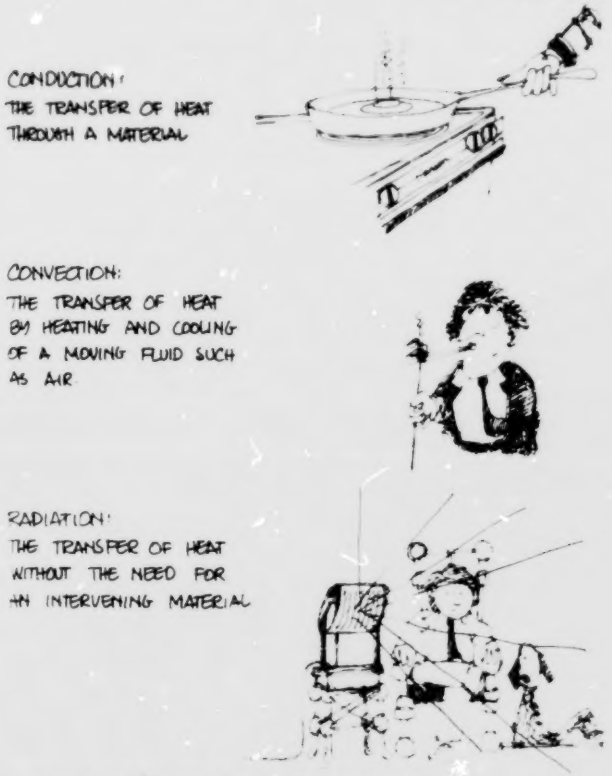

CONDUCTION:
THE TRANSFER OF HEAT THROUGH A MATERIAL
CONVECTION:
THE TRANSFER OF HEAT BY HEATING AND COOLING OF A MOVING FLUID SUCH AS AIR
RADIATION:
THE TRANSFER OF HEAT WITHOUT THE NEED FOR AN INTERVENING MATERIAL

FIGURE 2.4 HEAT TRANSFER MECHANISMS

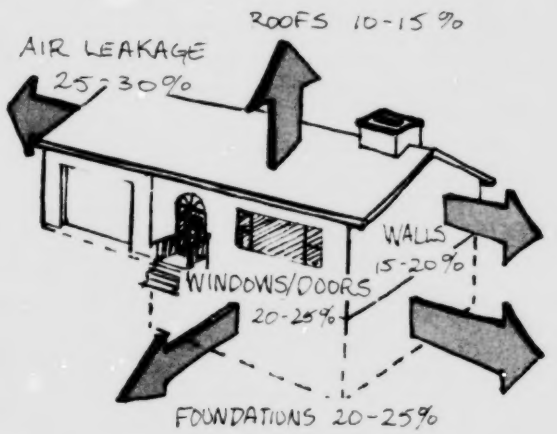


FIGURE 2.5 WHOLE HOUSE HEAT LOSS

3. Even if all the air could be removed leaving a perfect vacuum, the warm interior surface would radiate some heat to the cold exterior surface in the same way that the sun's heat reaches the earth.

If the stud space is filled with insulation it slows down the transfer of heat several ways. Insulation restricts conductive heat losses by trapping still pockets of air. It is these air pockets which provide the insulating function of the material. The insulation also serves the function of greatly restricting convective heat transfer by reducing the potential for air movement within the cavity. Finally the insulation reduces radiative heat transfer between surfaces by creating a barrier between the inner and outer wall. See Figure 2.6.

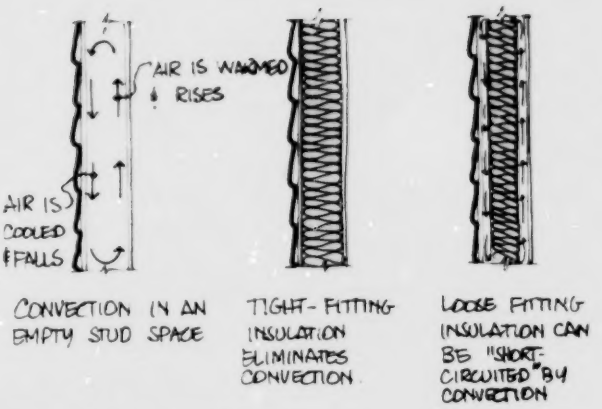

AIR IS WARMED & RISES
AIR IS COOLED & FALLS
CONVECTION IN AN EMPTY STUD SPACE
TIGHT-FITTING INSULATION ELIMINATES CONVECTION
LOOSE FITTING INSULATION CAN BE "SHORT-CIRCUITED" BY CONVECTION

FIGURE 2.6 CONVECTIVE EFFECTS IN A STUD WALL.

2.1.3. How Much to Invest in Energy Conservation Measures

Anything that saves energy saves money, but sometimes the cost can outweigh the benefit. Every millimetre of insulation saves energy. However, each additional millimetre of insulation saves a little less than the one before but it costs just as much. Common sense tells us that when benefits decrease while additional costs remain relatively constant, there is often a level beyond which the savings do not justify the additional cost.

There are several methods for evaluating the cost-effectiveness of energy-saving measures. The guide emphasizes the Principal, Interest, Taxes and Energy (PITE) Analysis. This approach takes into consideration the net change in monthly or annual occupancy cost due to the cost of energy conserving features and the corresponding reduction in energy costs. It identifies the purchase price increase whose principal and interest payments will be off-set by such a reduction. The other possible methods to measure cost effectiveness include payback period (length of time the additional purchase price for energy conserving features would be off-set by cumulative energy cost savings) and life cycle costing.

PITE

The PITE approach focuses on how the increase in monthly mortgage payments due to energy saving features can be off-set by the reductions in energy costs. Significant increases in purchase price may be totally off-set by operating cost savings in the first year (see Figure 2.7). As energy prices continue to increase, the annual operating cost savings will continue to grow. Therefore, even if the first year's energy savings don't quite off-set the added principal and interest payments, it is quite likely that within two to three years the increases in energy savings will more than cover the additional amount of principal and interest payments.

Other methods

Another measure of cost effectiveness for energy conserving options is payback period. This indicates how quickly the price premium is off-set by the savings in energy costs. The preferred maximum length of time will depend upon the period that the purchaser plans to stay in the dwelling. First time buyers may only remain in their houses for a period of three to five years before moving up to accommodation that will meet their longer term needs. Move up and move down buyers will likely remain in the home for a longer period of time (see Section 10).

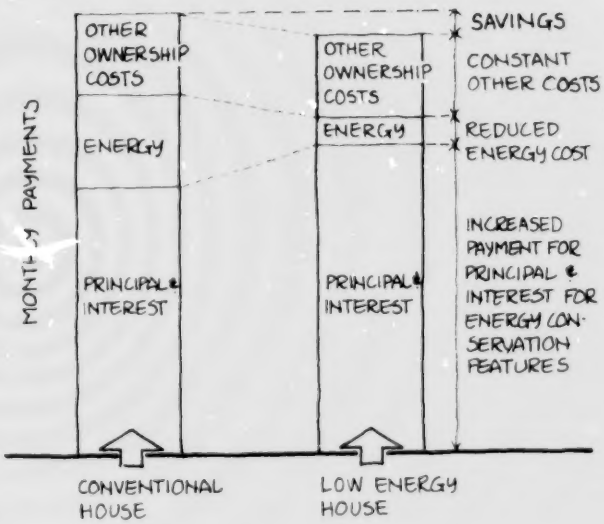


FIGURE 2.7 EFFECTS OF REDUCED SPACE HEATING REQUIREMENTS ON MONTHLY PAYMENTS

Life cycle costing can also be used as another method to compare future energy savings over a given number of years with the initial cost premium needed to realize these savings. This approach is a form of payback analysis whereby the payback period is equal to the estimated life of the dwelling or to the amortization period of the mortgage.

2.1.4 Energy Conservation and Human Comfort

There are four principal environmental factors which affect the comfort of a person inside a building. In order of decreasing importance they are:

- air temperature
- the presence of air currents (drafts)
- the temperature of surrounding surfaces
- relative humidity

The significance of each of these factors and the relation of each to energy conservation measures is discussed below.

Air Temperature

All houses must be equipped with heating systems capable of maintaining a temperature of 22°C at design temperatures on the coldest winter day. Design and balance of the heating distribution system and proper location of the thermostat will help achieve uniform temperatures throughout the house.

Presence of Air Currents (Drafts)

At any given room temperature, moving air will carry heat away from the human body faster than still air. Therefore, even when moving air is at room temperature, it will feel cooler. Drafts, then, rather than air temperature, often cause homeowners to turn up their thermostats. Conversely, the absence of drafts will make a lower temperature comfortable.

Measures taken to reduce air leakage in houses, such as those recommended in Section 3, will pay dividends not only in direct energy savings but also in improved occupant comfort — and therefore further energy savings since interior temperatures can be lower.

Temperature of Surrounding Surfaces

Even in a warm room, a person standing or sitting near a cold outside wall or window will feel cool because that person's body is radiating heat to the cold surface. A house with very little insulation, even though it might have a furnace large enough to maintain a high air temperature, can still be uncomfortable due to the presence of many cold surfaces. In new homes, present insulation standards have resulted in warmer interior wall surfaces.

Windows, on the other hand, even if double-glazed, are much colder than other interior surfaces and any improvements in their thermal resistance will yield a comfort bonus (see Subsection 5.8).

Relative Humidity

Maintaining comfortable humidity levels is an added benefit of today's energy efficient home. For comfort, humidity levels should be within 30 to 60% relative humidity during the heating season. Increased air tightness using the techniques described in Section 3 can result in higher humidity levels since uncontrolled air leakage is greatly reduced. Controlled ventilation systems as described in Section 4 are used to remove excess humidity as desired.

2.2 Design Considerations

Energy efficient design is based on an understanding of heat transfer mechanisms and the human comfort factors described above. This section will show how building shape, internal layout, siting and landscaping can be used to improve energy efficiency and owner comfort — often at little or no premium.

2.2.1 Recommendations

Dwelling Form

- Select the most energy efficient housing type that the market will accept.

External

- Plan the units to maintain simple compact forms, with the least amount of exterior surface. Avoid projections and indentations of the heated space.

- Use unheated building elements such as garages, vestibules, storage sheds, and porches to provide visual interest and variety in housing form. These elements can be used effectively as insulating air spaces and wind screens.

- Design shading devices that screen windows from the summer sun, but permit solar gain in winter.

Internal Layout

- Reduce the number of openings in north walls. Windows can be located on other walls, preferably the south wall. Even so, some north wall openings may be required for cross ventilation.

- Make use of passive solar winter heat gains. Concentrate glass areas on the south elevation, together with protective measures to deal with summer heat and glare; consider using sunrooms and glassed-in porches on the south side; and place slabs and massive elements such as fireplace enclosures so that they can store heat from the winter sun's rays passing through the south windows.

- Arrange floor plans and house siting to provide winter sunlight to the rooms when it will do the most good — the morning sun to the kitchen and bedrooms, perhaps — the noonday and afternoon sun to the living and dining rooms.

- Place non-living spaces on the north side wherever possible. Spaces such as bathrooms, utility rooms and mud rooms that require little, if any, natural lighting, can be aligned along north walls.

- Provide unheated vestibules and vestibule doors to reduce drafts in living space.

- Place furnace, furnace flue and fireplace centrally to get maximum advantage of heat transfer from these elements.

- Locate water heater centrally (in plan) with respect to kitchen, bathrooms and washing machine locations.

Siting and Landscaping

- Select south or east-facing slopes, clear of shading from neighbourhood houses and tall coniferous trees, wherever possible.
- Choose sites where north and west winter winds are at a minimum or where there is protection from them.
- Residential streets should run east-west wherever possible to provide maximum exposure for winter solar heat gain for houses on either side of the street.
- In siting the dwelling on the lot take advantage of any existing vegetation or earth forms to create windbreaks by placing the dwelling unit in the wind 'shadow'.
- Plant deciduous trees to provide summer shade for dwelling walls, windows (especially those on the west), and roof. Check with a landscape expert to ensure that the trees are located so that future root growth will not damage foundation walls.
- Use ground cover plants rather than paving on ground surfaces immediately adjacent to the south and west walls to reduce glare and reflected radiation.
- Plant windbreaks of coniferous trees to protect dwellings from prevailing winter winds. To be most effective these trees should be planted in at least two and preferably three rows in staggered formation because of their conical shape. The most effective location of a windbreak is upwind at distance of 1.5 to 2 times the height of the building.
- Use earth berms as windbreaks. Be sure to provide adequate drainage on the dwelling side of the berm.
- Take care to ensure that the orientation and design do not cause overheating on sunny days.

2.2.2. Dwelling Form

Generally, the greater the exterior surface area a building has in relation to its volume, the higher its heat losses will be. Figure 2.8 shows the relative heat losses for various forms of dwellings, all with approximately the same amount of liveable floor area and all insulated to Ontario Building Code minimum requirements.

The bungalow, two-storey house, and split-level entry unit are all free standing. The bungalow has the highest heat loss because it is relatively spread out and has the highest ratio of exposed surface area to volume. The bungalow is therefore the least energy-efficient house form.

The two-storey house more closely approaches the shape of a cube and therefore has a smaller ratio of surface area to volume. For this reason it requires less energy for space heating than a bungalow with the same floor area.

The detached split-level entry home is similar to the free standing two-storey house in its compact shape, but has a smaller total surface area to be heated. The split-level entry house is therefore more economical to heat than the two-storey house.

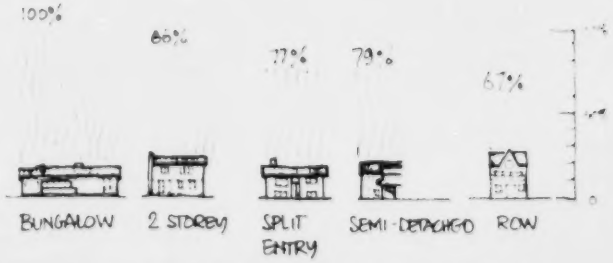


FIGURE 2.8 RELATIVE HEAT LOSSES BY DWELLING TYPE
HEAT LOSSES ARE SHOWN AS A PERCENT OF HEAT LOSS OF THE BUNGALOW OF SAME HABITABLE FLOOR AREA.

The semi-detached house is similar to the detached single family house, but as one of its walls is not exposed to the weather, it is more energy efficient.

Row housing units have both long walls sheltered from the weather (except for end units), making this the most energy efficient form of low rise housing.

Simple compact forms reduce the ratio of surface area to volume (Figure 2.9), and each projection or wall angle increases the area of exterior surface where heat can escape. An attached garage with heated space above it, for instance, exposes the floor of the overhead rooms to the cold and increases heat loss. Dormer windows also increase the surface area to be insulated, without increasing the floor area; and they are difficult to insulate thoroughly because of the irregular surface areas forming the dormer projections (Figure 2.10).

Interesting variations of a simple housing form can be achieved without sacrificing energy performance by using unheated building elements. Garages, vestibules and storage sheds can be planned around the main living space where they not only add visual interest, but also shelter and, to some extent, insulate the walls to which they are joined (Figure 2.11). These elements are particularly useful on north walls where they can serve as a buffer to winter winds.

Another way of providing visual interest is to use structural elements that offer climate control, such as porches, trellises, windscreens, awnings, shutters and small greenhouses (Figure 2.12). These elements improve the environment as well as the appearance of the home at no increase in heat loss.

FIGURE 2·9 SIMPLE FORM

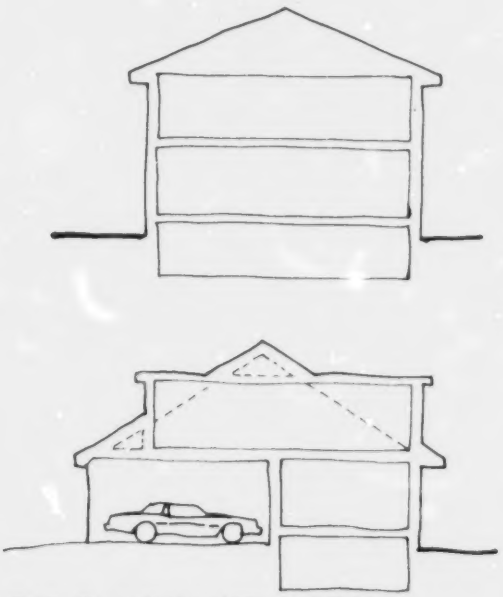


FIGURE 2·10 GARAGES AND DORMERS

GARAGES PROJECTING INTO THE FORM OF THE DWELLING AND DORMERS, TEND TO INCREASE INSULATED SURFACE AREA IN COMPARISON TO FLOOR AREA.

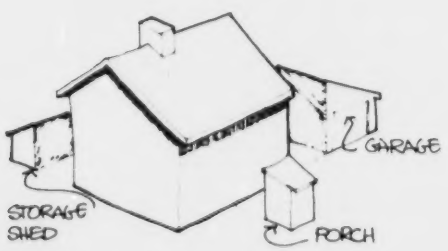


FIGURE 2·11
UNHEATED ELEMENTS

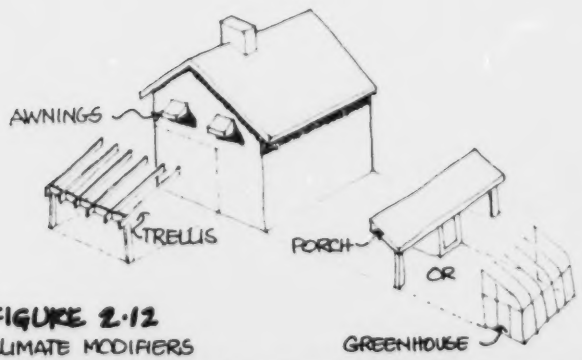


FIGURE 2·12
CLIMATE MODIFIERS

Built-in shading can improve energy efficiency while making the house more attractive. Correctly designed, shading devices protect windows from heat buildup due to summer sun, but make the most of solar gains during the winter. Figure 2.13 shows various alternatives. Figure 2.14 shows typical window dimensions for various room types and gives the factors used to calculate overhang dimensions according to degree of latitude at the site.

2.2.3 Internal Layout

The floor plan of the building influences the amount of energy it uses. Knowing how this happens can help builders select the most efficient layout for their homes.

Windows on the north side lose heat in winter, those on the east and west sides also lose heat, but get some heat back to the house from the sun. Builders should select plans that do not place the larger windows, such as those for living and dining rooms, on the north side. If north-facing windows are needed, they should be kept as small as possible.

Floor plans should be designed to place rooms and windows where they can take maximum advantage of available sunlight. In this way, sunlight can reduce household demands for lighting and heating (Figure 2.15).

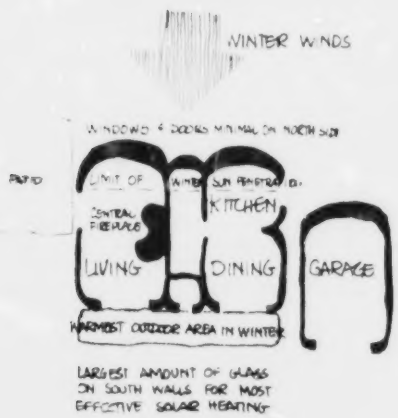


FIGURE 2.15 LAYOUT FOR WINTER SOLAR GAIN

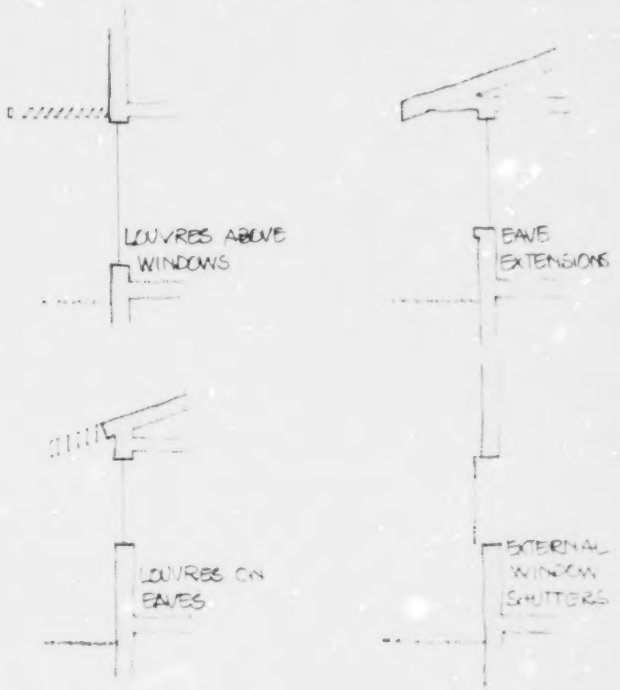
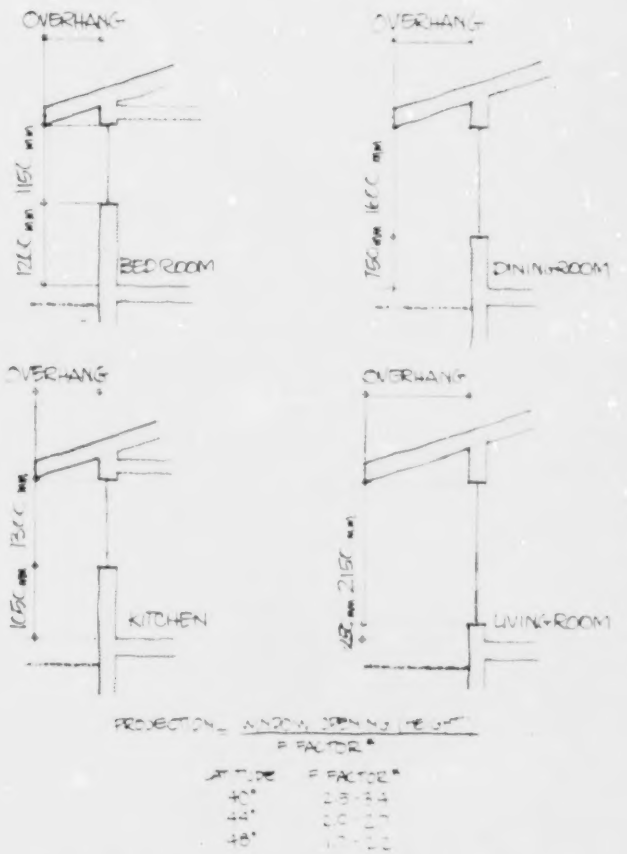


FIGURE 2.13
ELEMENTS PROVIDING WINDOW SHADING



PROJECTION = WINDOW SPANNING THE SILL / F FACTOR*

ALTITUDE	F FACTOR*
40°	2.5 - 3.4
44°	2.0 - 2.7
48°	1.7 - 2.2

*NOTE: SELECT A FACTOR ACCORDING TO YOUR LATITUDE. THE HIGHER VALUES WILL PROVIDE 100% SHADING AT NOON ON JUNE 21. THE LOWER (RECOMMENDED) VALUES UNTIL AUGUST 1.

FIGURE 2.14
EFFECTIVE SHADING

Non-living spaces such as bathrooms, utility rooms and mud rooms should logically be placed on the north side, because these rooms require little, if any, natural lighting.

Windows on the south side can actually provide a net heat gain in winter by allowing solar heat to enter the home. Siting houses on east-west streets provides the best opportunity for winter solar heat gains. Careful selection of a dwelling plan to fit the orientation of the lot will allow the large windows of the living and dining area to take advantage of the south exposure (see Figure 2.16).

Builders can take advantage of solar heat gain in a number of other ways.

- Use sun rooms and glassed-in porches as heat traps;
- Locate large masonry elements such as floor slabs and fireplaces where the winter sun will strike them. The solar heat they store during the day will be released at night.

Vestibules can improve comfort by reducing drafts when the front door is opened, especially in small homes where the entry opens directly into the living space.

Furnace and fireplace chimneys radiate heat, much of which is lost if they are located on outside walls. Placing chimneys in a central location keeps more of this heat in the house and also reduces the maximum length of warm air ducts or hot water heating pipes.

Similarly, heat loss from hot water pipes can be reduced if the tank is located close to points of use such as the kitchen, bathroom and laundry area.

2.2.4 Siting and Landscaping

Careful siting and landscaping can also improve energy efficiency in new housing at little or no additional cost to the home buyer (Figure 2.17).

In addition to the general climate of the area, each site has its own immediate climatic conditions governed by its view of the sun, exposure to prevailing winds, landscape and topography. All of these have a small but significant effect on the air temperature, wind and solar radiation around the dwelling. These effects can be improved or modified through design.

South or east-facing slopes are preferable to flat sites. Sites that are shaded on the south by tall coniferous trees or neighbouring buidings should be avoided.

Deciduous trees provide shade in summer, then lose their leaves and admit sunlight in winter. They reduce window heat gain by blocking direct summer sunlight penetration. This form of shading is particularly important for west-facing windows because normal overhangs are not as effective against low-angled sun's rays in the late afternoon. Shade provided by trees also lowers the ground surface temperature so heat gain through a tree shaded window is reduced by less heat radiation from the ground and by the cooler air temperatures. (Figure 2.18).

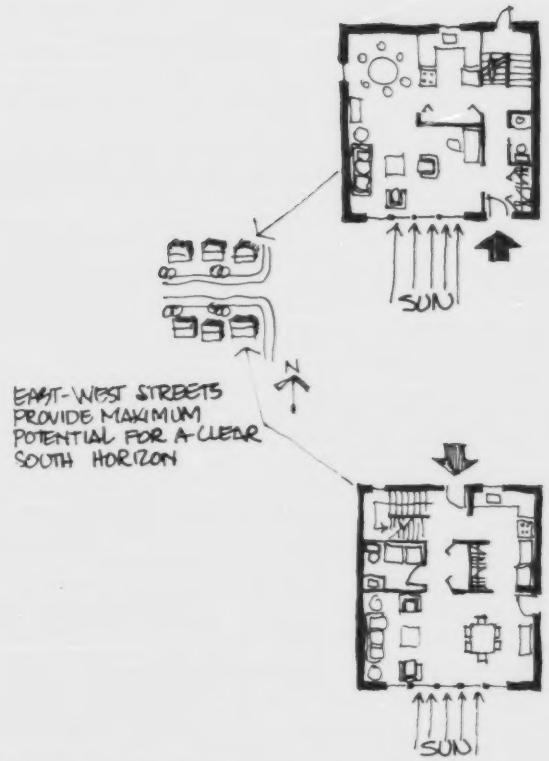


FIGURE 2·16 STREET ORIENTATION & ITS EFFECT ON FLOOR PLANS

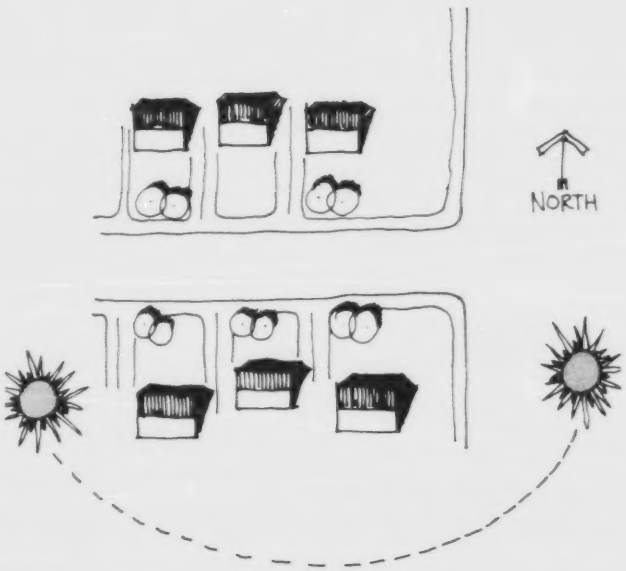


FIGURE 2·17 EAST-WEST STREETS PROVIDE MAXIMUM POTENTIAL FOR WINTER SOLAR GAIN.

Another way to reduce glare and reflected radiation adjacent to homes is to use ground cover plants, rather than paving, on ground surfaces beside south and west walls (Figure 2.19).

Coniferous trees can provide a winter wind break (Figure 2.20). To be most effective they should be planted in at least two and preferably three rows in staggered formation, because of their conical shape. The best place for a wind break is upwind at a distance of 1.5 to 2 times the height of the building. At this distance the wind will be reflected up and well over the building, reducing pressure on the building's windward side and pulling action on its leeward side.

Figure 2.21 summarizes many of the possibilities for energy conservation related to site planning and landscaping. Many of these features can be included at little or no cost if the builder is aware of them during the site selection and planning process.

2.2.5 Other Considerations for Passive Solar Gain

Builders should be aware of two factors. First, improved siting and landscaping to maximize passive solar gain should be considered secondary to improving energy efficiency of the design and construction of the various components of the building envelope: walls, attics, windows, etc.

Secondly, too much exposure to the sun through siting and positioning of large south-facing windows can lead to temporary periods of overheating on sunny days. This effect, called temperature swing, results from solar gains causing interior temperatures to rise significantly above the thermostat setting. If the temperature becomes unacceptably high, occupants will have to open windows. The following cooling down will likely result in lowering the temperature below the thermostat setting, thereby ultimately increasing the demand for space heating.

For these reasons, designs for passive solar gain must be carefully considered to ensure that optimum benefits are achieved.

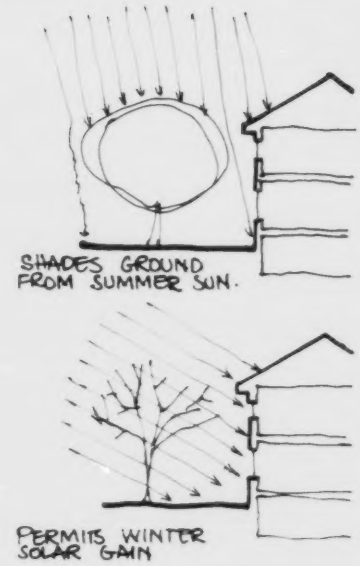


FIGURE 2·18 REDUCTION OF SUMMER GLARE & GROUND RADIATION

FIGURE 2·19 REDUCTION OF GLARE BY GROUND COVER.

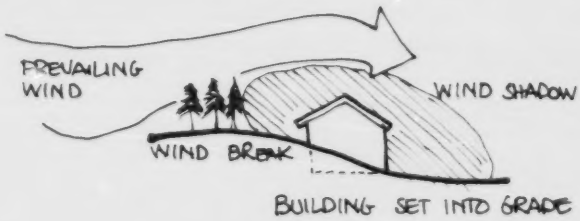


FIGURE 2·20 PROTECTION FROM WINTER WINDS

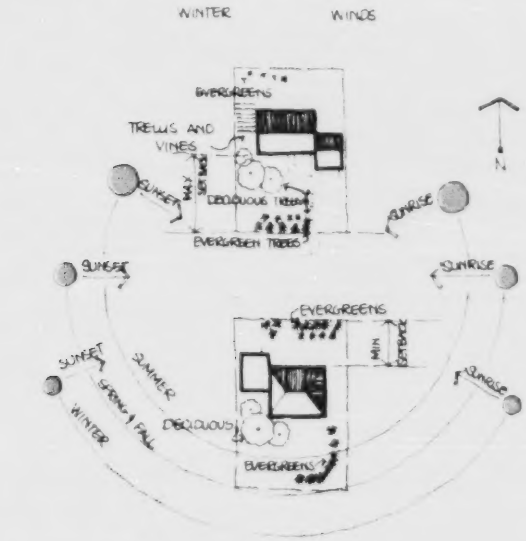


FIGURE 2·21
LANDSCAPING FOR CLIMATE CONTROL

Section 3
Controlled Air Infiltration

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Air leakage is a characteristic of housing that can have a major affect on energy costs, occupant comfort and on the structural integrity of the building. This section explains the importance of reducing uncontrolled air leakage in Canadian housing, and how this can be achieved. A cautionary note is provided to remind builders that controlled ventilation is needed to offset potential problems in tightly built houses.

3.1 Recommendations

- A continuous air barrier should be installed throughout the building. This air barrier might be made up of sheet materials such as a durable polyethylene, or a combination of the structural elements of the house which have been carefully sealed.

- The air barrier of the house should be located on the warm side of the building envelope to prevent moisture migration into the insulated assembly.

- When installing a secondary air barrier on the exterior of the house, the material must allow the escape of moisture to the exterior.

- Materials used in the sealing of different components of the air barrier should be durable and compatible with their intended use. Sealants for use with polyethylene sheets must maintain their flexibility, while gasketing used in sealing structural elements of the house should provide adequate resiliency to accommodate small changes and movement in the various building assemblies and components.

- A fan door depressurization test can be used to determine the relative airtightness of a building compared to conventional and superinsulated buildings.

- Airtightening techniques, such as those mentioned above, should only be undertaken in conjunction with a strategy that can provide a continuous and controlled source of fresh air to the house. This fresh air source is essential for the health and safety of the house occupants.

3.2 Air Leakage

Until recently Canadian houses were constructed in a way that allowed significant quantities of outdoor air to leak into the house and a corresponding amount of warm air would leak out of the house. This condition results in significant heat loss, cold drafts, and the potential for movement of water vapour into the building assembly.

This air leakage (convection) is one of the significant sources of heat loss in conventional housing (about 20 to 25% - see Figure 2.1) For air flow to occur, either into or out of the house two conditions must be in place — 1) there must be a hole and 2) there must be a pressure difference between the interior and exterior. Pressure differences are created by three mechanisms:

- **Stack effect**: The tendency of air to rise as it is warmed. As the warm air rises it exerts a positive pressure at the top of the building, and a negative pressure at the lower levels of the house. The result will be warm air leaking out of the house through leaks and cracks in the ceiling and cooler air entering through holes in the lower levels of the house.

- **Wind effect**: The pressure created by a wind on the windward side of a house will force cold air into the house. On the leeward side of the house, the wind moving away from the house creates a suction or negative pressure that will cause warm air to leak out of the house.

- **Exhaust effect**: The operation of exhaust appliances and any fuel burning appliance will result in house air being forced to the outside. A negative pressure is thus created on the interior of the building leading to the infiltration of colder outside air.

To prevent envelope related air leakage, some sort of barrier against air leakage (an air barrier) must be installed in all new housing. While this air barrier can take many forms, it often utilizes a material that can also prevent the movement of moisture into the building envelope.

3.3 Moisture Related Problems

In Canada, moisture movement is of greatest concern during the winter months when warm moist air inside the house may leak into the colder areas of exterior walls and ceilings. Condensation and freezing can result. This may cause a number of moisture related problems.

- If insulation in walls and/or ceilings becomes wet the efficiency of the materials can be severely reduced.

- High moisture levels in the building shell can cause rot and eventually lead to structural failure of the building.

- Some building materials such as gypsum board or composite wood products may break down when exposed to high moisture levels or condensation.

Because these problems occur out of sight, within the fabric of a building, they may build up until they reach serious proportions that may be expensive and/or difficult to correct. This is why the prevention of moisture movement into the walls and ceilings is so important.

3.4 Moisture Movement

On any given day more than 20 kg of water vapour could be put into the air in a house. The moisture sources listed below are those which are homeowner related. Of equal significance is the moisture which is put into the house air by the seasonal drying of the house and by construction moisture.

Source	Amount of Water Vapour Generated
Cooking (3 meals)	1 kg per day
Dishwashing (3 meals)	0.5 kg per day
People (family of four)	5 kg per day
Bathing — shower	0.25 kg each time
Bathing — tub	0.05 kg each time
Clothes washing	2 kg each time
Clothes drying	12 kg each time

This large amount of moisture moves through the exterior shell of the building to the outside in two ways:

- Diffusion
- Air Leakage

Diffusion describes the tendency for water vapour to move from areas of high concentration to areas of lower concentrations. In a house, this means that moisture in the inside air will tend to move through any moisture permeable material (such as wood and plaster) to reach the lower moisture concentration of the outside air. This type of moisture movement can be reduced by using a low permeability material (such as polyethylene) that is often called a **vapour barrier** (Figure 3.1).

Air Leakage is the major vehicle of moisture transport. Until recently, it was thought that diffusion was the most significant form of moisture transport in a home. However, recent research has indicated that air leakage is responsible for most moisture movement into walls and ceilings (Figure 3.2). As a result, building specialists tend to stress the importance of an **air barrier** rather than a vapour barrier in minimizing moisture movement through the building fabric.

To illustrate the difference between moisture movement via diffusion versus movement via air leakage, consider a 1 square meter wall section in a typical house (see Figure 3.3). Over a normal Ontario heating season, that section of wall will **diffuse** 1/3 of a litre of moisture into the outer envelope. In contrast, if there is a small 2 x 2 cm hole or crack somewhere in that same wall, it will have the ability to move over 30 litres of moisture via **air leakage** during the heating season.

Therefore, installing a good quality air barrier throughout a building will preform the dual task of reducing energy losses and minimizing the possibility of moisture related damage.

While the importance of a vapour barrier has diminished, codes require that a vapour barrier still be incorporated in all new construction.

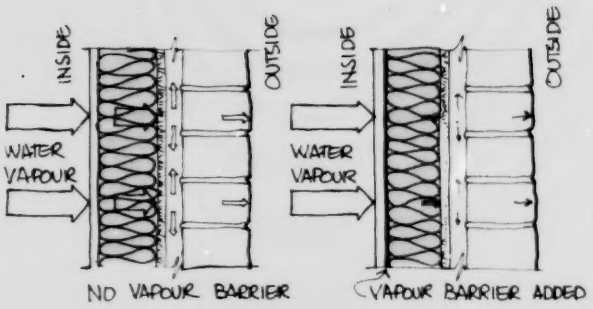

FIGURE 3.1 VAPOUR DIFFUSION – THROUGH THE MATERIALS

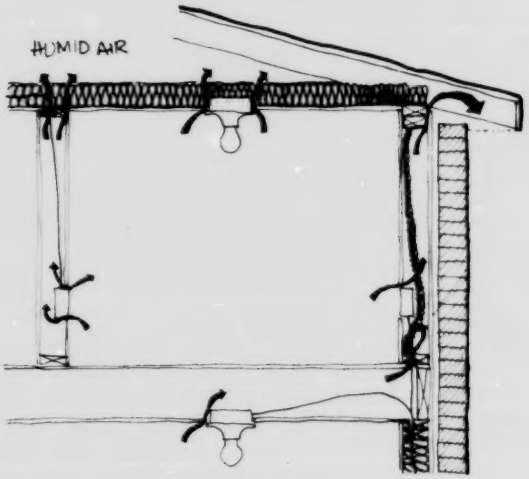

FIGURE 3.2 AIR LEAKAGE – THROUGH THE HOLES

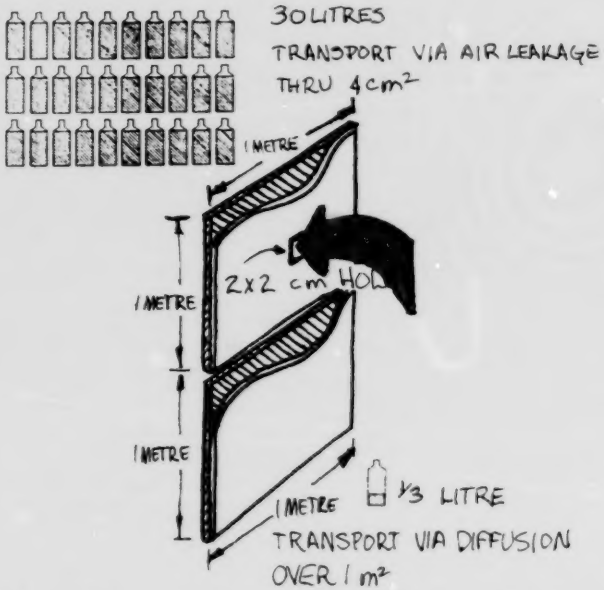

FIGURE 3.3 MOISTURE TRANSPORT OVER ONE HEATING SEASON (OTTAWA CONDITIONS)

3.5 Air Barriers

There are a number of approaches that can be used to achieve a high quality, long life air barrier in a house. Factors common to all air barrier approaches include:

- It is best located on the warm side of the wall.
- It should be installed so that it is continuous across the entire building envelope (including the basement).

The section below discusses some of the air barrier approaches and materials that can be used.

3.5.1 Polyethylene

The most common air barrier approach involves wrapping the inside envelope of the house with polyethylene sheets. Airtightness is ensured by overlapping and caulking all breaks or seams in the plastic with a non drying sealant such as an acoustical sealant. This type of sealant will not dry or crack when compressed between two sheets of poly over a solid material. It ensures the long term airtightness of all seams. Given its non drying nature, it is not a suitable sealant for exposed surfaces.

While there are many types of "poly", polyethylene sheathing purchased for use as an air barrier should meet a number of requirements. The most important of these requirements include:

- It must be at least 6 mil thick.
- It must be made from new material.
- It must have passed certain tests of uniformity and strength.
- If the material is to be exposed to sunlight for extended periods during construction, it must be UV (ultraviolet) stabilized to prevent breakdown of the plastic.

These requirements are presently being incorporated into a Standard For Polyethylene Air Barriers currently being developed by the plastic industry.

If a low permeability material like polyethylene is used for an air barrier, it will also reduce the amount of vapour diffusion that will take place, acting as an air/vapour barrier

3.5.2 Structural Air Barriers

An alternative air barrier approach involves the use of structural components of the building envelope (principally drywall) to create a continuous air barrier. All junctions between drywall, floors, subfloors and joists must be sealed with a sealant or gasket. All penetrations in the envelope created by electrical outlets, windows, doors, etc. must also be sealed (Figure 3.4).

A vapour barrier installed in conjunction with a structural air barrier can be provided by using a vapour barrier paint or by using 2 mil polyethylene.

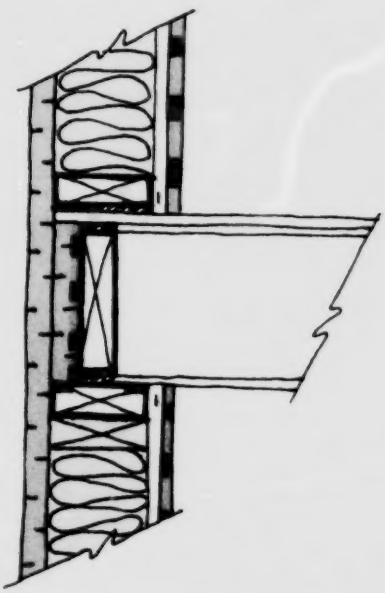

FIGURE 3·4 DRYWALL AIR BARRIER

3.5.3 External Air Barriers

One of the more recent innovations in air barrier technology has been the development of external air barriers. An external air barrier can be wrapped and sealed around the exterior of a house. It may take the form of a sheathing paper or as a backing material to an insulated sheathing. The material is designed so that it will allow moisture to travel out through the barrier via diffusion while restricting the movement of air in or out of the house.

The application of an exterior air barrier should be **in addition to the primary interior air barrier**. However, this material does act as an excellent weather barrier underneath the outside cladding of a building. When an external air barrier is used as a weather barrier, its air barrier qualities can enhance the air tightness of a structure and can improve the efficiency of insulation materials (see Figure 3.5).

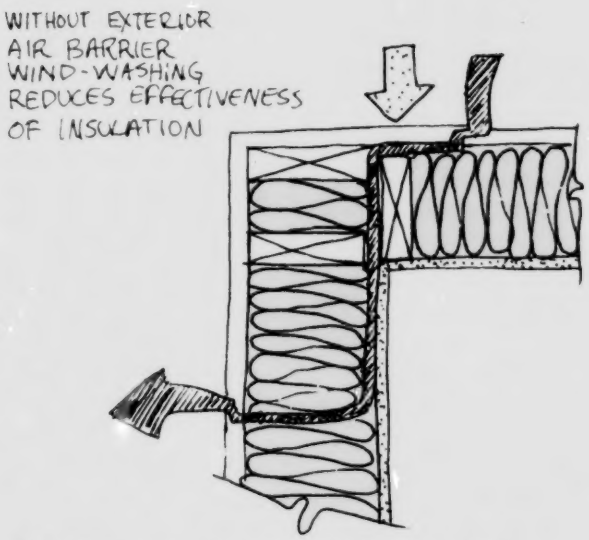

FIGURE 3.5 WIND PENETRATIONS

3.5.4 Sealants

In many cases the air barrier of the building will not be continuous— by itself. Seams in the material, or the junction between structural elements of the house require careful sealing. The selection of the proper sealing material for the right job is of critical importance. Any material used for air/vapour barrier sealing should be of a high quality and rated for long life (at least 15-20 years). There are many different types of sealants and each has specific applications. Some of these sealants and their application are listed below.

Acoustical Sealant

- Best for sealing polyethylene air or vapour barriers where they overlap.

Silicon Sealant

- Flexible, high quality, all purpose sealant good for all applications except porous surfaces like concrete and poly vapour barriers.

Butyl Based Sealants

- Generally has lower lifetime than many sealants. Good for masonry. Tends to shrink over time.

Acrylic Sealants

- Good for all sealing applications except poly vapour barrier.

Urethane Foam

- Excellent for areas where cracks or gaps exceed 2 cm. Often this sealant is used between window and door frames and rough gaps in and around the foundation wall. Suitable only for interior application, will break down in direct sunlight.

Foam and Rubber Gaskets

- Used extensively in structural air barriers to seal between horizontal junction points such as: foundation/sill plate, sill plate/header, header/ subfloor, etc. Can also be used in conjunction with caulking to seal large cracks or gaps.

Plastic Electrical Pans

- For encasing electrical fixtures and boxes that would otherwise penetrate an air/vapour barrier. Should be sealed directly to the air/vapour barrier and around any wire penetrations.

Weatherstripping

- Should be used on all windows and doors. Choose durable and high quality materials.

To be effective, all sealants must be applied to absolutely clean surfaces.

3.6 Air Tightness Testing

Once a house is constructed, it is possible to determine the relative air tightness of the house using a blower door (Figure 3.6). The blower door consists of a large fan which exhausts the house air at a rate in excess of 1500 L/s. As the air is drawn out of the house, the difference in pressure between the inside and outside as well as the fan speed is measured by a computer.The computer is able to calculate a number of values that can then be compared to other houses that have been tested.

The value most often used in air tightness testing is called the Equivalent Leakage Area (ELA). The ELA is a value given in cm^2 that describes the size of a hole that might occur in a house if all the air leakage cracks, gaps and holes were brought together. Thousands of houses have been tested across Canada using the blower door. As a result the ELA statistics for a particular house can be compared to a wide variety of sizes and types of houses.

The blower door can also prove a useful tool in identifying the location of the leaks in the house. The outside air leaking into the building can be easily felt, or identified with a smoke pencil as it passes through the gaps in the house envelope.

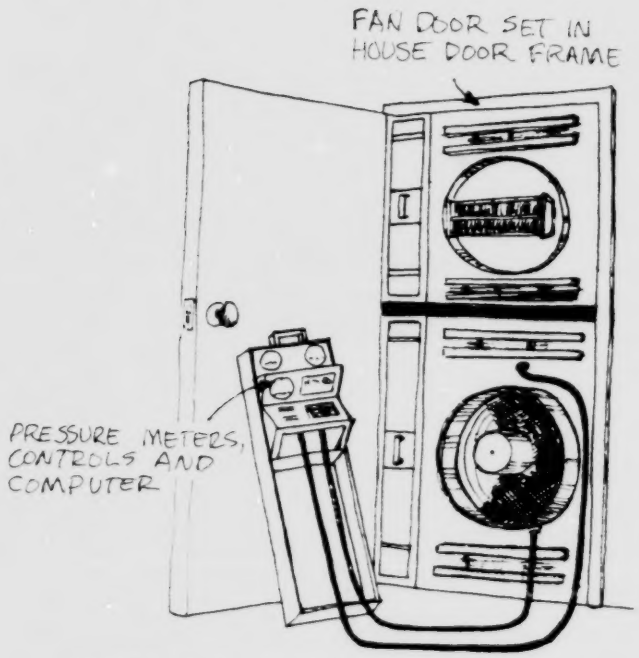

FIGURE 3.6 BLOWER DOOR ASSEMBLY

3.7 Fresh Air And Moisture Control

Necessarily, a home sealed against air and moisture leakage must also have some sort of controlled ventilation strategy. Ventilation is required both to reduce interior humidity levels and to provide a supply of fresh air to the occupants. Airtightness affords energy savings and prevents potential moisture damage from occurring in the building shell. It also offers the opportunity to incorporate a fresh air ventilation system that is specifically designed for a house and its specific needs. The actual ventilation rate can also be regulated depending on need.

Contrast this with a conventional leaky house, where there is no guarantee that the house is going to leak at the right time, in the right place, at the right amount to control humidity, odours and pollutants in the house.

The next section describes the ventilation considerations that must be incorporated into a well built home incorporating airtightness features.

Section 4
Provisions for Air Change and Moisture Control

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This section deals with an important factor in determining the energy efficiency and health and safety aspects of a house. The supply of fresh air is particularly important given the increasing use of new construction methods in conventional house construction which is resulting in tighter envelopes. The importance of air supply is explained and measures to maintain air quality are provided. Concepts of a central intake and exhaust system, considering primary heating air supply, are outlined. This information is followed by a discussion on moisture control, contaminant control, and heat recovery.

4.1 Recommendations

- **Incorporate a means of providing ventilation in a controlled way to use the minimum amount of outdoor air necessary to control air quality and humidity levels.**
- **Provide a sufficient supply of combustion air for furnaces and domestic hot water heaters.**
- **Fireplaces and wood-burning appliances used in energy efficient homes should have well-sealed doors and an externally ducted supply of combustion air.**
- **Incorporate a heat recovery device in the ventilation system where high moisture loads necessitate unusually high air change rates or in very cold areas where even moderate air change rates result in high energy costs.**
- **Inform purchasers or renters of the importance of controlling humidity and how the ventilation system may be used to do so.**

4.2 Importance of Air Supply to the House

Air is needed in the house for three distinct purposes; to provide ventilation, to replace air exhausted by appliances, and for combustion purposes.

4.2.1 Ventilation or Air Change

Every house needs to have its indoor air changed periodically. This removes and dilutes the contaminants that can build up in the indoor environment. These contaminants include:

- water vapour in the form of humidity.
- contaminants produced by the activities of the people in the house, such as breathing, cooking, smoking, etc.
- contaminants which are emitted from the building materials, contents or items stored in the house.

This air change can occur by natural means through leaks in the building envelope driven by natural forces such as wind, air buoyancy effects or, as is getting more common in this era of tight building construction, by mechanical means. When the air change is forced by mechanical fans it is referred to as ventilation.

4.2.2 Make-up Air

Most houses can have a number of appliances which expell air from the house, such as exhaust fans, clothes dryers, externally vented central vacuum cleaners and, perhaps most importantly, combustion appliances such as fuel fired furnaces and hot water heaters and fireplaces. Table 4.1 lists the exhaust capacity of several typical house appliances.

One can readily imagine that if these devices are forcing air out of the house, and if there is no easy entrance for incoming fresh air to replace it, the air pressure inside the house will be reduced below that of the outdoors. A slight negative pressure in the house is usually beneficial since it will restrict leakage of moist indoor air into the building component, but if it becomes too great some negative consequences can occur.

The first and most important of these is that it could result in flue backdrafting. A flue or chimney operates by making use of the buoyancy effects of warm air in the chimney. If the negative pressure in the house is high enough, it can overcome this chimney draft, and exhaust gases from the combustion appliance may enter the house rather than going up the chimney (Figure 4.1).

Another possible consequence of excessive negative pressures in the house is that some contaminants produced outside the house or in the building shell can be sucked into the house. One concern is radon gas which is a naturally occuring gas resident in many soils. If the house is under a negative pressure this gas could be sucked into the house through leaks and cracks in the basement area.

4.2.3 Air Supply for Heating Equipment

This subject is dealt with in detail in Section 6 of the book. Makeup air for fuel burning appliances is required to minimize the potential for combustion gases backdrafting into the house. Because of the potentially dangerous implications of combustion appliance backdrafting, the provision of exterior combustion air should be viewed as a requirement of an energy efficient house (Figure 4.2). It is important that the builder understand that this is a requirement over and above the need for ventilation in housing.

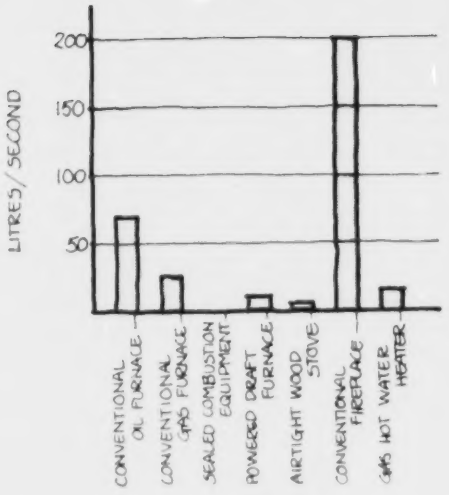


TABLE 4.1 AIR FOR COMBUSTION & DRAFT CONTROL — REQUIREMENTS OF VARIOUS TYPES OF COMBUSTION EQUIPMENT

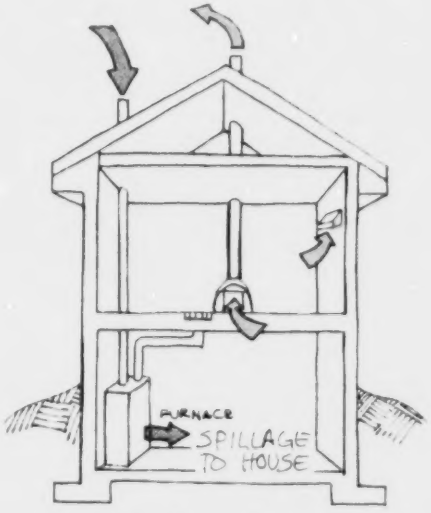


FIGURE 4.1 BACKDRAFTING

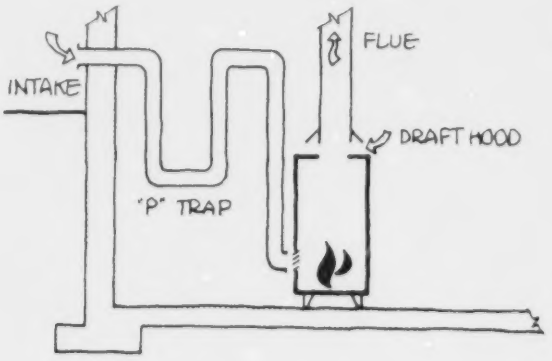


FIGURE 4.2 ADD-ON AIR INTAKES

4.3 Required Air Change and Ventilation Rates

Since any fresh air entering the house must be heated to room temperature, excessive air change or ventilation results in higher heating costs. With the tighter envelopes of energy efficient housing construction, it is possible to control the amount of ventilating air to match the actual needs in the building.

4.3.1 Ventilation Quantities

Studies have been done to determine ventilation requirements for a variety of building types and uses, including housing. For residential uses the American Society of Heating, Refrigeration, Air Conditioning Engineers Inc. (ASHRAE) Standard 62-1981 suggests that each habitable room in a house be supplied with a continuous source of fresh air at a minimum rate of 5 L/s (10 cfm) per habitable room.

This requirement is independent of house size. The definition of habitable room includes bedrooms, living room, dining room, family room, kitchen, bathrooms, powder rooms whether they be on the main floor or in the basement. Combination living room/dining rooms should be considered the equivalent of two rooms.

ASHRAE 62-1981 also suggests that certain rooms, the kitchen and bathrooms, be supplied with the capability of exhausting at much higher rates when required. The suggested installed exhaust capacity is 50 L/s (100 cfm) for kitchens and 25 L/s (50 cfm) for each bathroom.

Table 4.2 illustrate the requirements for a seven room house. The ventilation system is sized to provide fresh outside air on a continuous basis at the minimum rate of 35 L/s, with a peak rate of an additional 25 L/s. Furthermore the kitchen and bathrooms should have exhaust fans to bring up the exhaust capacity of these rooms to 50 and 25 L/s respectively. The exhaust capacity could be met through the central system if it was equipped with two speed fans. This latter approach has an additional advantage in that it is easy to control high speed operation with a humidity control as well as a manual control so that high humidity levels in the house are automatically reduced by increased ventilation.

It should be noted that some publications express required ventilation rates in terms of air changes per hour. In fact, the National Building Code and some Provincial Government codes use this designation for describing unit exhaust capacity requirements. This approach can be misleading. Actual ventilation requirements are much more dependent on the number of occupants and how the space is used rather than size or volume of the dwelling. Current inititives in setting the standards by such organizations as the Canadian Standards Association and the R-2000 Program are relying primarily on per room calculation because it is a better analogy for building use.

Table 4.2

Minimum Continuous Fresh Air Supply
7 Rooms @ 5 L/s (10 cfm) = 35 L/s (10 cfm)
Additional Capacity for Peak Ventilation of: 25 L/s (50 cfm)
Total Ventilation System Capacity = 60 L/s (120 cfm)
Exhaust 1 Bathroom @ 25 L/s (50 cfm) + 1 Kitchen @ 50 L/s (100 cfm) = 75 L/s (150 cfm)

4.3.2 Makeup Air Requirements

As mentioned in Section 6, the air required for combustion and draft control of heating appliances is one type of makeup air requirement which has been treated separately in most codes and standards and therefore should be dealt with as required by those codes and standards.

The negative pressure in a house caused by an exhaust fan will be dependent on the magnitude of the unbalanced exhaust flow and how tight the building envelope is. One method of determining the tightness of the building is the blower door or fan depressurization test described in Section 3.6. It is usually expressed in the term Equivalent Leakage Area or Air Changes per Hour at 50 Pa.

In most houses, if air requirements for heating equipment and fireplaces have been taken care of, separate makeup air provisions for exhaust fans should only be of concern if exhaust fan capacity exceeds 75 L/s. If the builder has any reason to suspect especially tight construction, either from the construction methods used or from fan test results which show an ELA of less than .02m^2 or an Air Change Rate at 50 Pa of less than 1.5 AC/hr, there may be some concerns at exhaust flow rates of less than this.

This would be of particular concern with naturally aspirating combustion appliances. Perhaps the best way of dealing with this is a field test after construction is complete. The builder should turn down the thermostat until the chimney has had time to cool. Then he should turn on all exhaust equipment after any filter has been removed (including the lint trap of the clothes dryer). He should then have somebody turn up the thermostat and watch the furnace. If after it comes on the chimney draft is quickly established and the exhaust products go up the chimney, he can feel fairly comfortable that backdrafting will not be a problem. If the flow is not established quickly, additional makeup air provisions should be incorporated. This can be done by providing a separate duct to supply the largest exhaust appliances or by increasing the size of the fresh air duct to the heating equipment.

4.4 Central Ventilation Systems

It is becoming increasingly common in modern houses to install central controlled ventilation systems to provide a continuous supply of fresh air to the house. The following sections describe the elements of an effective ventilation system for a house and illustrate some examples of systems which incorporate these elements.

The elements of an effective ventilation system are:

- a source of fresh uncontaminated outdoor air
- the ability to distribute fresh air continuously to all habitable rooms
- the ability to exhaust those areas of particularly high contaminant generation at their source so they don't get distributed around the house.
- air driver(s) (i.e. fans) which force the air change and balance the supply and exhaust flows so that the house operates at a zero, or slightly negative, pressure.

4.4.1 Fresh Air Supply Systems

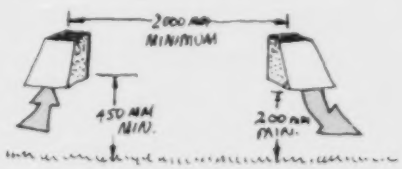
The fresh air supply system of a house requires a fresh air inlet and distribution system to each room. The type of distribution system will depend primarily on the type of heating system in the house. In houses with forced-air heating the heating ducts make a readily available distribution system (Figure 4.3). If fresh air is introduced to this duct network and the furnace's circulation fan is kept running continuously, fresh air will be distributed to all rooms served by the heating system. In houses without forced-air heating, it is necessary to provide a distribution system which would generally have much smaller ducts than that required for a forced-air heating system (Figure 4.4). The driving force to move the air could be provided by a fan in the distribution system or by one in a centralized exhaust system which would then have to run continuously.

The location of the fresh air inlet warrants careful consideration. It must be placed well away from any source of potential contamination including:

- driveways and garages
- garbage areas
- gas meters, oil fill pipes, exhaust outlets of any kind.

The opening itself must be protected from wind, rain, snow, insects, rodents and located such that it is not easily blocked by snow, leaves and paper (Figure 4.5). Homeowners should be advised to inspect them frequently and clean up any accumulated lint or debris.

One relatively simple way of getting the fresh air into a heating duct system is to make a direct connection of the inlet duct to the return air duct of the furnace. This does, however, have some disadvantages. The flow rate through the fresh air duct will depend on the furnace circulating fan's operation. Running the furnace fan continuously at high speed consumes a significant amount of electricity and, in some cases creates additional noise. Having a two-speed fan which operates on low speed continuously and kicks into high speed when the furnace is on reduces these concerns, but as the ventilation rate will increase when the furnace comes on, an additional energy penalty will be incurred.



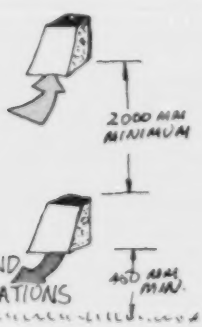


FIGURE 4.5 HRV INLET AND OUTLET LOCATIONS

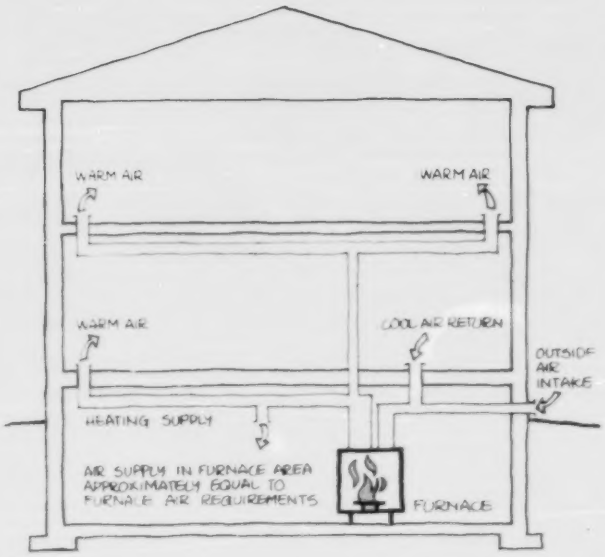


FIGURE 4.3 AIR INTAKE SYSTEM WITH FORCED AIR HEATING

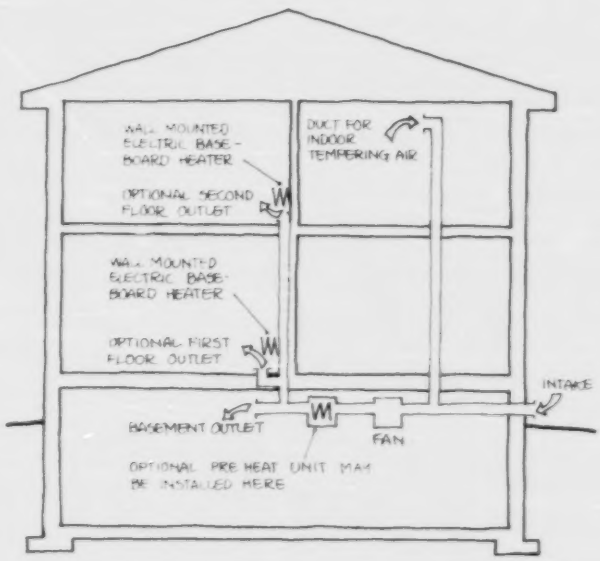


FIGURE 4.4 AIR INTAKE SYSTEM WITHOUT FORCED AIR HEATING

Cold air, unless well mixed with warm return air, may cause cold spots and condensation on the heat exchanger of the furnace which could lead to premature failure. This concern can be reduced by ensuring that the air entering the furnace is adequately warmed either by mixing with sufficient return air or by preheating incoming air to an acceptable level.

Another method of using the heating system to distribute air without some of these problems is to have a separate fresh air fan which provides air to the heating system through an indirect connection. (Figure 4.6). This approach is much less susceptable to variations in ventilation flow rate with changes in furnace fan speed.

In baseboard air heated houses, an independent fresh air ducting system is recommended. Particular attention must be paid to occupant comfort. Incoming air can be cold and if this is blown directly into the occupied zone it could be a source of much discomfort to the occupant. These issues can be alleviated by a number of measures including:

- installing a tempering heater such as a duct heater
- careful placement and specification of fresh air inlets in each room.

As any air conditioning contractor will tell you, ceiling and high wall mounted outlet grills are a much better way of distributing cool air than the regular diffusing type of floor grills (Figure 4.7). There are also floor grills which are better for cool air than the regular diffusing type; these are the ones with straight vanes that blow the air up along the wall where it gets more time to mix with the room air before entering the occupied zone of the room. If the outlets were placed under the baseboard heaters additional tempering of the incoming air is provided.

4.4.2 Exhaust Equipment

Because of the continuous supply of fresh air required, it is usually necessary to have a continuous exhaust . This ensures that the house will operate in a balanced mode.

Exhaust air should be drawn from those areas of the house which have the highest contaminant generation levels — the kitchen, bathrooms, laundry areas and special use areas such as workshops and hobby rooms. This could be provided by individual exhaust units or by providing one central, continuously operating, fan with a duct system drawing air from these rooms. This continually operating exhaust can be considered to make up part or all of the exhaust capacity requirements discussed in Section 4.3.1.

The best location for exhaust air grills is high up on interior walls. In the kitchen it should be placed well away from the stove to avoid grease build-up (Figure 4.8). The outside exhaust outlet should be away from areas where it would create a nusiance and well away, at least 2 metres, from the fresh air inlet.

Because the balance of the continuous supply and the continuous exhaust requires a free flow of air, all partition doors in rooms without individual exhaust air grills, such as bedrooms, should be well undercut or have louvered grills (Figure 4.9).

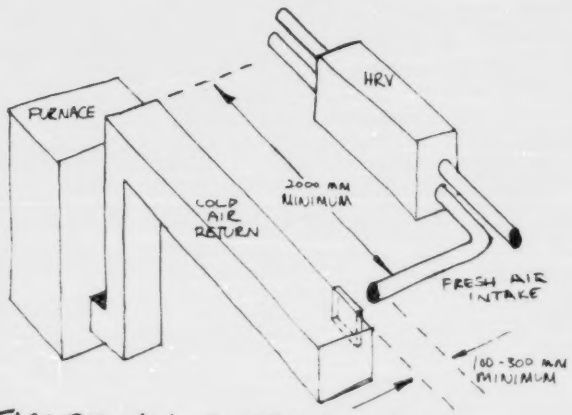
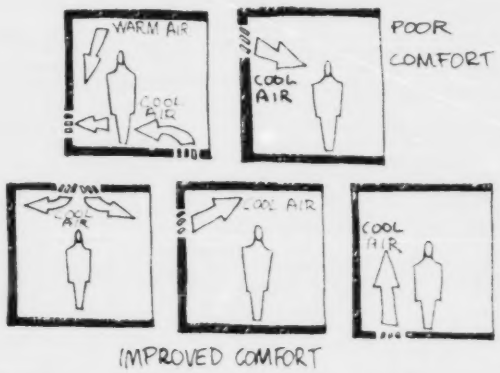


FIGURE 4·6 CLEARANCES FOR VENTILATION AIR



IMPROVED COMFORT

FIGURE 4·7 GRILLE LOCATION

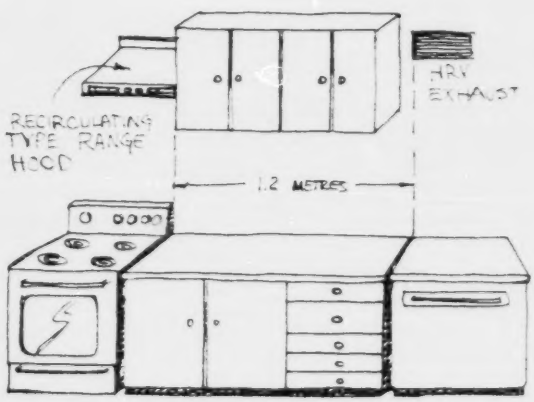


FIGURE 4·8 KITCHEN EXHAUST

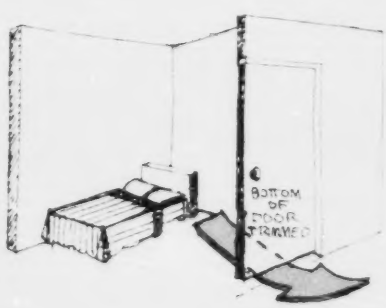


FIGURE 4·9 AIR DISTRIBUTION

4.4.3 Heat Recovery Systems

The exhaust air that is expelled from a house contains a significant amount of heat. This heat loss from the house has to be made up by heating up the incoming air. There are devices which recover the heat from the outgoing air stream and supply it either to the incoming air stream or to other household energy requirements such as the hot water heating system. These are generically termed heat recovery ventilators (HRV). The amount of energy that they recover from the exhaust depends on the volume of exhaust air that they handle and the efficiency of the unit.

When considering the use of a heat recovery ventilator one must recognize that its primary function is ventilation. The secondary function is to recover a portion of the waste heat from the exhaust stream. The value of the energy recovered should be compared with the incremental cost of using a heat recovery ventilator system as compared with another ventilation system providing the same ventialtion rate.

The heat recovery ventilator also has some other non-monetary advantages. They temper the incoming air with the recovered heat, reducing equipment and comfort problems attributed to cold air entry to the house. They are inherently capable of providing a balanced supply and exhaust air flow minimizing any problems caused by positive or excessive negative pressures in the house.

There are a number of different types of HRVs, the most common of which has two fans which direct the warm indoor air and cold outdoor streams through alternating paths in a heat exchanger. The heat is transferred from the outgoing stream to the incoming stream. This is shown in Figure 4.10. There are also units which rather than use this fixed plate arrangement, have a spinning disc or wheel which moves through both air streams collecting heat from the outgoing stream and dissipating it to the incoming stream (Figure 4.11).

One fairly new development in the HRV field is the use of heat pump exhaust heat recovery systems. These use a heat pump system similar to a refrigerator to extract heat from the outgoing air stream. This heat which can now be upgraded to a higher temperature by the heat pump action can be supplied to either the incoming airstream or to the hot water system (Figure 4.12). One advantage of this approach is that one can use an exhaust only system without having to bring the incoming air immediately adjacent to the exhaust stream. This approach does require that careful thought be given to where and how outdoor air is entering the building. Some of the Heat Pump units can also be used to supply a small amount of cooling in the summer.

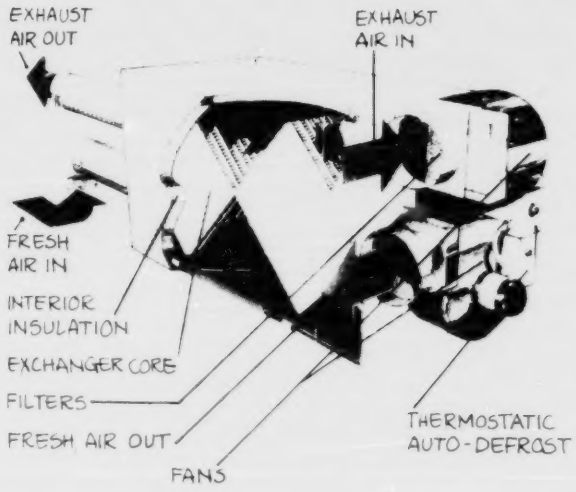


FIGURE 4·10 HEAT RECOVERY VENTILATION SYSTEM (PLATE TYPE)

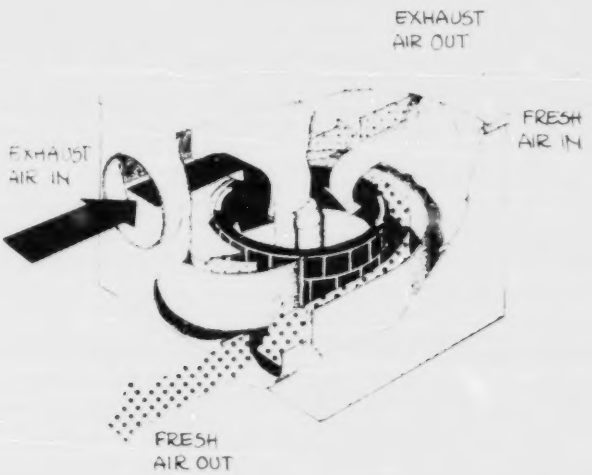


FIGURE 4·11 HEAT RECOVERY VENTILATION SYSTEM (SINGLE HEAT WHEEL TYPE)

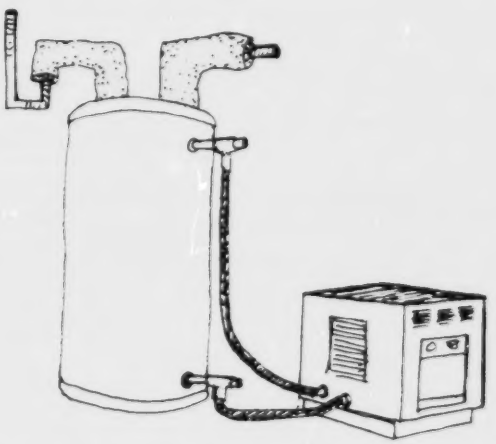


FIGURE 4·12 HEAT PUMP WATER HEATER

HRV's are a relatively new item for houses, and initially there were both design and installation problems which caused concerns. Consequently some efforts have been made in recent years by standards organizations to ensure uniform design rating methods and installation practices. This has resulted in a number of preliminary standards. One is CSA 439 - Standard Testing and Rating Methods for HRVs. The actual testing has been carried out at the Ontario Research Foundation, and uniform reporting of information on standard data sheets is available. An example is shown in Appendix F. This allows a comparison of the ventilation and heat recovery performance of individual units. Another standard (CSA C444 M1985) The Design and Installation of Heat Recovery Ventilators outlines how these units should be installed and requires that the installation be done by an installer who is certified by the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI) for installing HRV's.

4.4.4 Special Provisions for Cold Air Ducts

Makeup air and fresh air exhaust air ducts after heat recovery ventilation are all cold air ducts running through heated interior space. If not properly protected, humidity in the warm indoor air will condense on the cold surfaces of the duct. Therefore, these ducts must be insulated and have vapour barriers to protect them from indoor moisture. Insulation levels should be R-2 (RSI .4) and the vapour barrier must be complete from beginning to end. Particular care should be taken in tying in the ducts' vapour barrier to the vapour barrier of the wall. To simplify this procedure special materials have become commonly available; one is a pre-insulated flexible duct which has a tough plastic outer vapour barrier and the required level of insulation. This system is highly recommended.

4.4.5 Detail Design of Ventilation Systems

The HRAI's Residential System Design Manual contains all the information required to compute required air capacity and duct sizes, but, it must be recognized that controlled ventilation systems are a relatively new inclusion in housing. It is therefore advisable to deal with designers who have been certified under the HRAI's certification procedure for the installation of HRVs. These people will have had a stronger grounding in requirements of ventilation systems for houses whether or not they incorporate a HRV.

4.5 Sources and Control of Contaminants in the House

Many contaminants are produced in a house — either by the building materials themselves or by the occupant and their activities. The prime purpose of ventilation is to dilute and remove these contaminants from the indoor environment. This is not the only approach to limiting build up of the contaminants. Obviously, limiting the source rate of contaminants will limit exposure levels.

4.5.1 Contaminants Produced in the House

There are a host of possible contaminants that are produced in the house. Some are produced by the building materials themselves or things stored in the house. These would include formaldehyde which is emitted from the glues in many particle boards, furniture, etc. as well as chemicals from household products and cleaners. Other contaminants produced by the occupants and their activities include odors, carbon dioxide and, perhaps the most well known to builders, water vapour in the form of humidity.

Excessive humidity in the house will probably first be noticed as condensation on windows on cold days. This will happen — depending on the temperature and the insulation value of the window —at about 30-50% relative humidity. The condensed water coming off the window could damage interior surfaces.

A broader concern is that this condensation process could be happening in concealed places in the building elements themselves. This can lead to rot and serious damage. It is therefore desirable to limit the levels of humidity in the air to that required for comfort and health, generally considered to be about 35-50% R.H. Maintaining this level can be done by controlling the sources of water production or by removing the moisture through ventilation.

Because of the highly variable nature of moisture production, it is desirable to incorporate a ventilation system which can operate at two or more speeds and can be controlled by a humidity controller (often known as a dehumidistat). With such an arrangement, the increase in humidity occurring at times of high moisture generation will automatically increase the ventilation rate and therefore the moisture removal rate to maintain the balance between production and removal.

4.5.2 Contaminants Produced Outside of the House

Contaminants can enter from outside the house through the fresh air inlet or through leaks in the building fabric itself. The former obviously relates very closely to the careful selection of the fresh air inlet location as discussed in Section 4.4.1. As mentioned in Section 4.2.2 the outdoor contaminant of most concern is radon which is resident in the soil. Measures for reducing entry of radon into houses include:

- ensuring a well sealed basement
- limiting negative pressures in the house
- using a ventilation scheme that exhausts air from the basement directly without transferring it into the living floors

The basic approach of sealing and limiting negative pressures is also effective where there is reason to suspect that there are contaminants produced by parts of the external building fabric. A good example of this in recent years was Urea Formaldehyde Foam Insulation (UFFI) in exterior walls. Emission of formaldehyde from UFFI into the house is greatly reduced by ensuring an interior air barrier and limiting negative pressures in the house. For this reason, exhaust only ventilation systems are not recommended for houses with UFFI.

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Options for Improving the Building Shell

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The building shell consists of the walls, roof, windows and doors — all the elements which separate the indoor environment from the outdoor environment. The shell can be improved to yield worthwhile savings in energy by increasing its thermal resistance and by making it as air-tight as possible. These improvements should only be undertaken when costs, benefits, possible negative consequences and alternate methods of improvement have been fully considered. This Section addresses these considerations for each of the elements of the building shell.

5.1 Installing the Air Barrier

Installing the air barrier is an important part of energy efficient construction. This subsection suggests a range of good practices and techniques.

5.1.1. Recommendations

- Install the air barrier on the warm side of the insulation (Figure 5.1). The barrier should be installed no more than 1/3 of the total insulation level into the assembly.
- Use large-sheet polyethylene (minimum 6 mil) for air/vapour barriers, applying it in large sheets to mimimize the number of seams(Figure 5.2).
- Lap all joints in the air/vapour barrier by one framing space and seal them with flexible caulking compound or suitable tape.
- All joints should be supported by solid backing such as a stud, ceiling joist or plywood sheathing, and should be mechanically supported by either the wallboard or other solid material.
- Restrict the number of penetrations through the air barrier. Eliminate electrical outlets and fixtures on exterior walls and insulated ceilings to the extent permitted by codes. Locate attic hatches in carport or garage ceilings, in end gables or some place other than in the insulated ceiling of the house. Carefully seal any penetrations in the air barrier.
- Structural air barrier detailing requires the use of resilient gasketing between the elements of the air barrier. A separate vapour barrier will be required.
- For discussion of air barriers see section 3.5. For further information builders should request the Energy Mines and Resources booklet entitled "Air Vapour Barriers". Additional detailing is provided in the R-2000 Builders' Manual available from the Canadian Home Builders' Association.

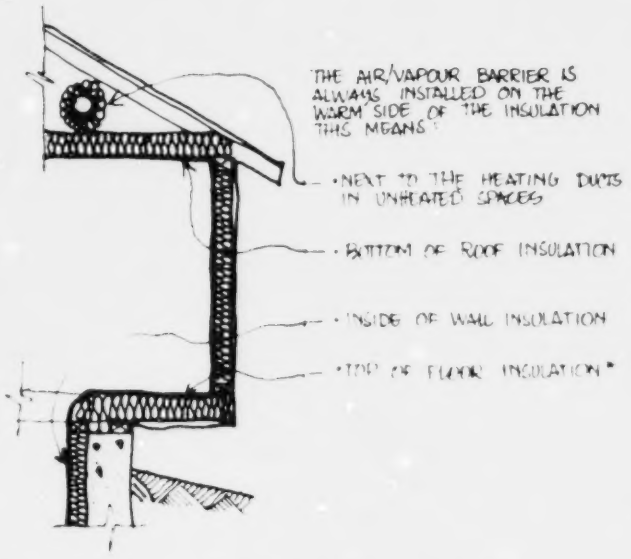

THE AIR/VAPOUR BARRIER IS ALWAYS INSTALLED ON THE WARM SIDE OF THE INSULATION THIS MEANS:
• NEXT TO THE HEATING DUCTS IN UNHEATED SPACES
• BOTTOM OF ROOF INSULATION
• INSIDE OF WALL INSULATION
• TOP OF FLOOR INSULATION*

FIGURE 5·1 LOCATION OF AIR VAPOUR BARRIER

* AIR/VAPOUR BARRIER IS NORMALLY NOT REQUIRED ON FLOORS WITH PANEL - TYPE SUBFLOOR SINCE THE SUBFLOOR PROVIDES AN ADEQUATE AIR BARRIER AND DOWNWARD LEAKAGE OF WARM AIR IS LIKELY TO BE MINIMAL IN ANY CASE BUT WHEN IT IS USED, IT SHOULD GO ON TOP

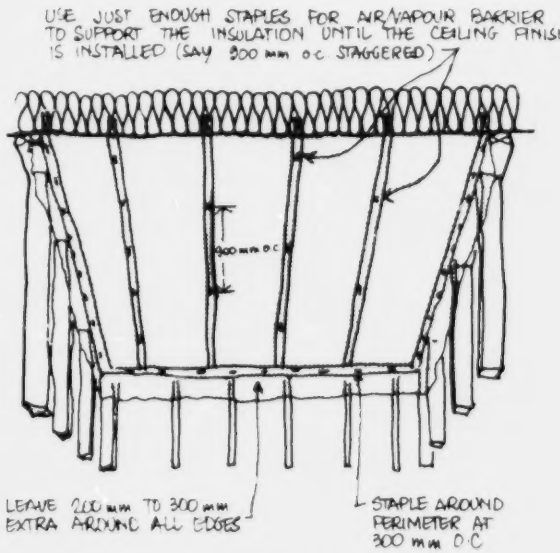

USE JUST ENOUGH STAPLES FOR AIR/VAPOUR BARRIER TO SUPPORT THE INSULATION UNTIL THE CEILING FINISH IS INSTALLED (SAY 900 mm o.c STAGGERED)
600 mm O.C
LEAVE 200 mm TO 300 mm EXTRA AROUND ALL EDGES
STAPLE AROUND PERIMETER AT 300 mm O.C

FIGURE 5·2 INSTALLATION OF AIR/VAPOUR BARRIER ON CEILINGS

5.1.2 General Considerations

In Subsection 3.3. it was explained that the most important function of the air barrier is to block the movement of warm humid air from inside the house into the shell of the house. It must also be repeated that a vapour barrier, although of secondary importance, is required as part of the house envelope, but it need not be continuous if it is to act only to retard vapour diffusion.The air barrier must be as nearly continuous as possible, minimizing the likelihood of any air entering the exterior cavities of the house (Figure 5.3).

Location

The air and/or vapour barrier must be installed on the warm side of the wall assembly to prevent water vapour from reaching the theoretical 'dew point' — the temperature at which the water vapour condenses out of the air as water. While typically this will result in the air and vapour barrier being located directly behind the wallboard, alternative approaches can be employed. Many builders want to recess the air barrier into the envelope to allow for the electrical and plumbing services to be installed without penetrating the barrier. The barrier may be installed and additional framing installed with some additional insulation (Figure 5.4). As a rule of thumb, however, **no more than one-third of the total RSI value of the insulation of the cross-section should be on the warm side of the vapour barrier.**

Air Sealing Penetrations

In conventional construction the air barrier is discontinuous through interior partitions, floor assemblies, and around service penetrations (electrical and plumbing fixtures). Airtight construction requires that these conventional breaks in the air barrier be properly sealed (Figure 5.5).

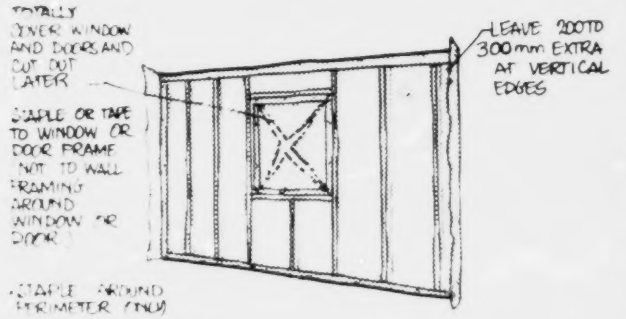


FIGURE 5.3 INSTALLATION OF AIR VAPOUR BARRIER ON EXTERIOR WALLS

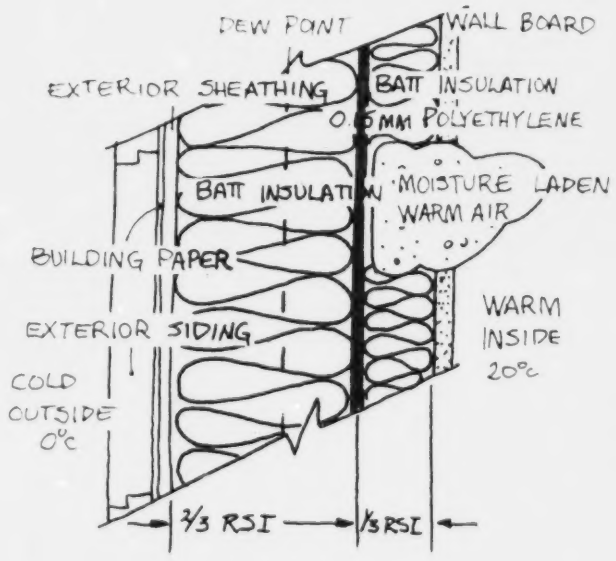


FIGURE 5·4 RECESSED VAPOUR BARRIER

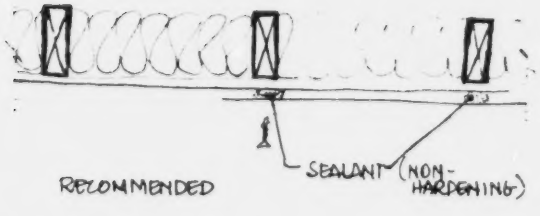


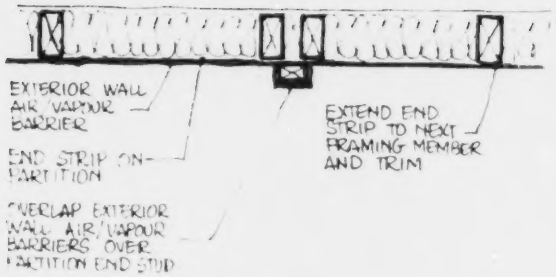
FIGURE 5·5 AIR/VAPOUR BARRIER JOINTS

Connecting strips of the air barrier, which wrap around headers, between floors, and around partition walls, allow for an effective seal (Figure 5.6). Specialty products are available for allowing relatively easy air sealing of the holes in the air barrier created by electrical boxes and switches and plumbing vents. Details for many of the options are presented in the following pages.

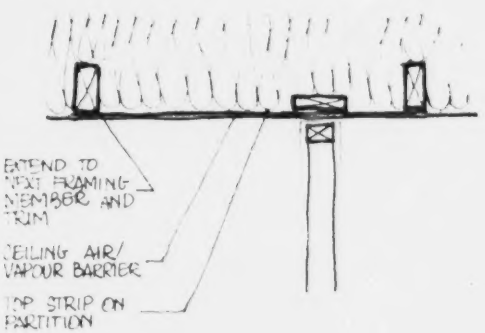
One common weak point in the air barrier is the attic access hatch in the ceiling. This is most easily avoided by locating the hatch in an outside gable wall, or in the carport of an attached garage. Where it is necessary to locate the hatch inside the house, it must be insulated and weatherstripped (Figure 5.7).

Air Barrier Detailing

Figures 5.8 to 5.11 inclusive provide illustrations of good air sealing practices. The drawings assume that 6 mil polyethylene sheeting is used in the combined function of an air and vapour barrier. Sealing of the seams of the material with acoustical caulking is suggested. The air/vapour barrier techniques recommended here, if followed faithfully, will result in a house with a high degree of airtightness.

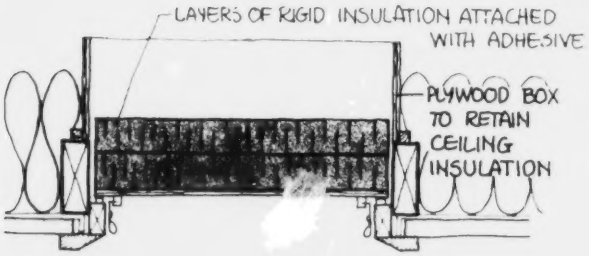

EXTERIOR WALL AIR/VAPOUR BARRIER
END STRIP ON PARTITION
OVERLAP EXTERIOR WALL AIR/VAPOUR BARRIERS OVER PARTITION END STUD
EXTEND END STRIP TO NEXT FRAMING MEMBER AND TRIM

A) EXTERIOR WALL - INTERIOR PARTITION INTERSECTION



B) CEILING - INTERIOR PARTITION INTERSECTION

FIGURE 5.6
AIR/VAPOUR BARRIER JOINTS AT INTERSECTION



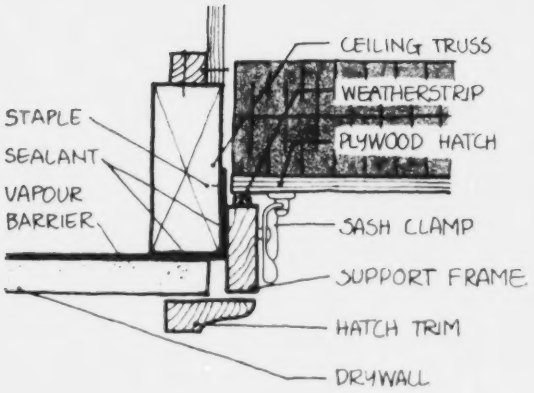


FIGURE 5.7
SUGGESTED ATTIC ACCESS HATCH DETAILS
PREFERRED ATTIC ACCESS IS THROUGH AN END GABLE OR THROUGH AN ENLARGED ROOF VENT.

NOTE

Some form of controlled ventilation will be required in these houses if condensation problems are to be avoided. This is especially true if the house is electrically heated.

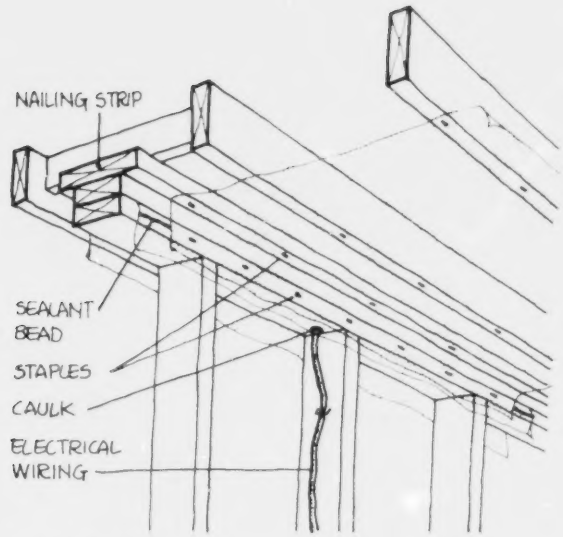
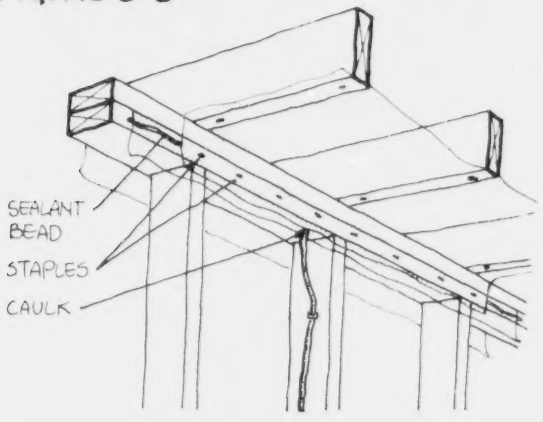


FIGURE 5·8



A SIMPLER METHOD IS TO INSTALL THE AIR VAPOUR BARRIER AND DRYWALL PRIOR TO INSTALLING THE INTERIOR PARTITIONS

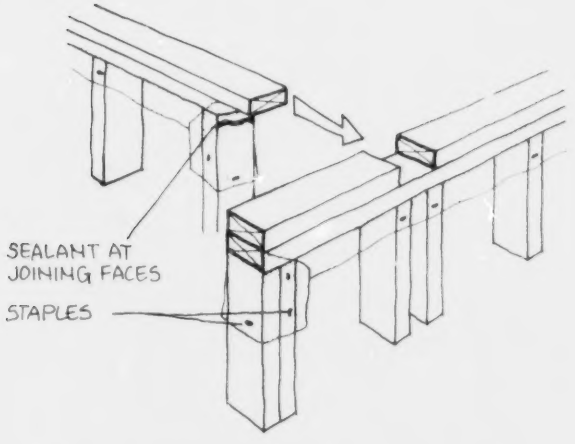


FIGURE 5·9 INSTALLATION OF AIR/VAPOUR BARRIER ON TOP AND ENDS OF INTERIOR PARTITION WHEN THIS METHOD OF CONSTRUCTION IS USED

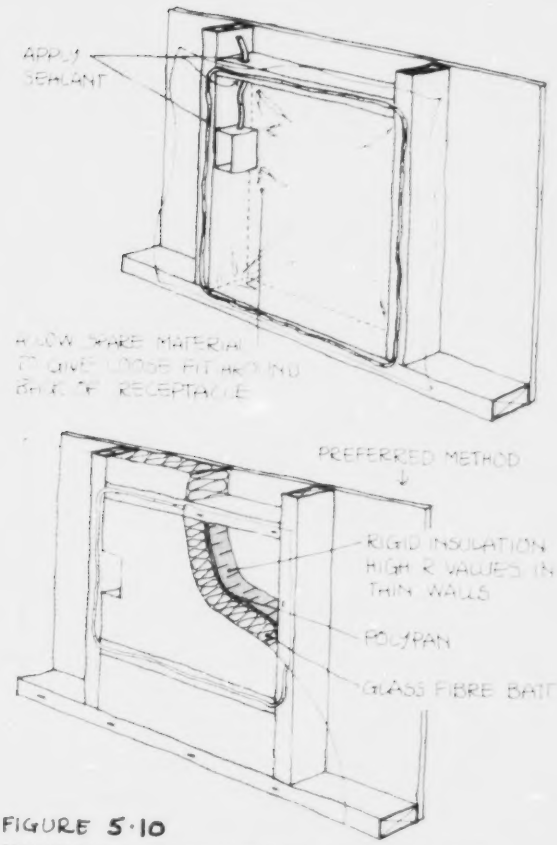


FIGURE 5·10
MAINTAINING CONTINUITY OF THE AIR/VAPOUR BARRIER AT ELECTRICAL BOXES

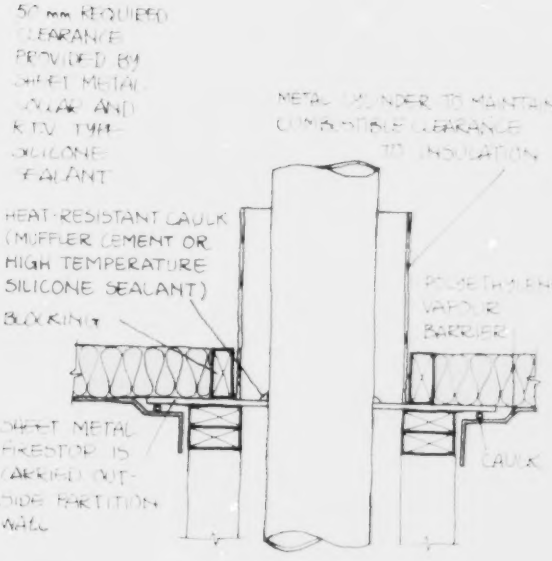


FIGURE 5.11

POTENTIAL FIRE HAZARD: KEEP INSULATION AT LEAST 75 mm AWAY FROM THE SIDES OF RECESSED LIGHT FIXTURES. DO NOT PLACE INSULATION OVER SUCH FIXTURES SO AS TO ENTRAP HEAT.

5.1.3. Alternative Air/Vapour Barrier Techniques

New approaches have been developed to provide an effective air barrier for the house envelope using a continuous rigid membrane of plywood or drywall to provide the air barrier. A separate vapour barrier using polyethylene, a specially formulated paint or other proprietary systems will be required to minimize vapour diffusion . These methods have been successful in achieving high levels of airtightness, and have the advantages of allowing the air barrier to be accessible for future upgrading. Use of these methods require professional advice. An example of this type of approach can be seen in Figure 5.12.

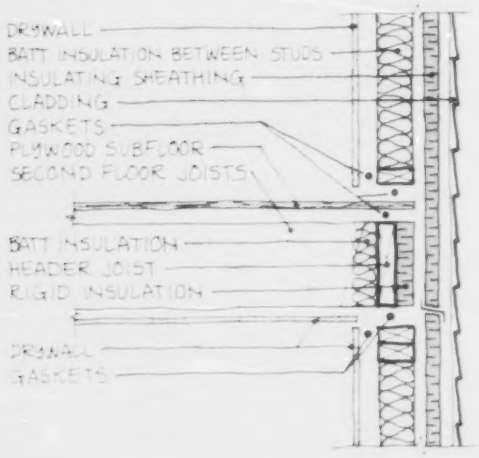


FIGURE 5.12 b) WALL SECTION USING PAINT AIR VAPOUR BARRIER

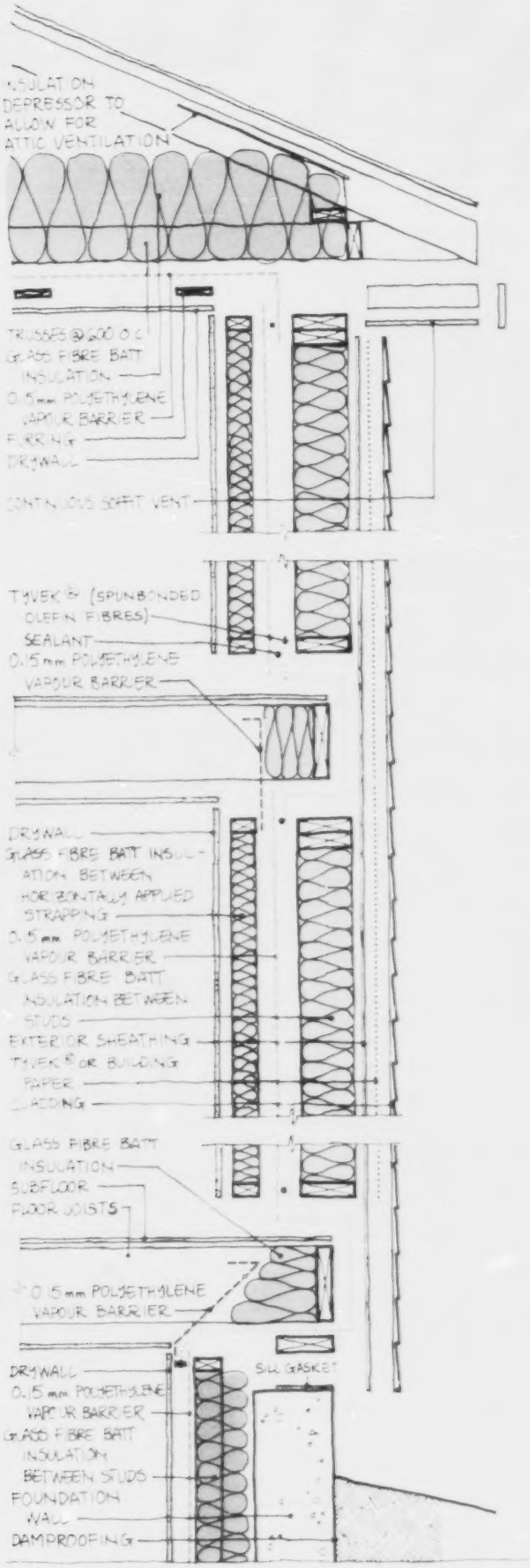


FIGURE 5.12 a) CONVENTIONAL WALL SECTION USING POLYETHYLENE VAPOUR BARRIER

5.2 Insulation

The following subsections present options for increasing the thermal resistance of the insulated portion of the building shell.

5.2.1. Calculating RSI Values

The Ontario Building Code specifies mimimum RSI values for insulation installed in the different areas of the house envelope. The exterior cladding, sheathing and interior finish add to the thermal resistance of an insulated frame wall, while the studs reduce it. CMHC Builders' Bulletin No. 267 and the 'Measures for Energy Conservation in New Buildings' published by the Associate Committee of the National Building Code specifies the total thermal resistance of the assembly, including the contributions of exterior cladding, sheathing and interior finish but **not** including the effect of wood framing. As the framing members of the house can account for as much as 20 percent of the area of the above grade house envelope, the reduction in overall RSI value caused by the framing might be taken into account when calculating heat losses.

Calculating the RSI value of a building assembly is simply a matter of adding up the RSI values of the individual components and the RSI values of the thin films of still air in contact with the surfaces. RSI values for various materials are given in Appendix B.

It is often necessary to use insulation batts in cavities which are not as deep as the batts are thick. For example 150 mm batts might be used in a wall built with 38 x 140 studs. The resulting compression reduces the thermal resistance of the batts but the reduction in the RSI value is not proportional to the reduction in thickness.

Figure 5.13 shows the approximate relationship between the amount of compression and reduction in RSI value. For example, a 150 mm batt inserted into a 140 mm cavity is compressed to 93% of its free thickness. However, the batt still retains about 96% of its original RSI value.

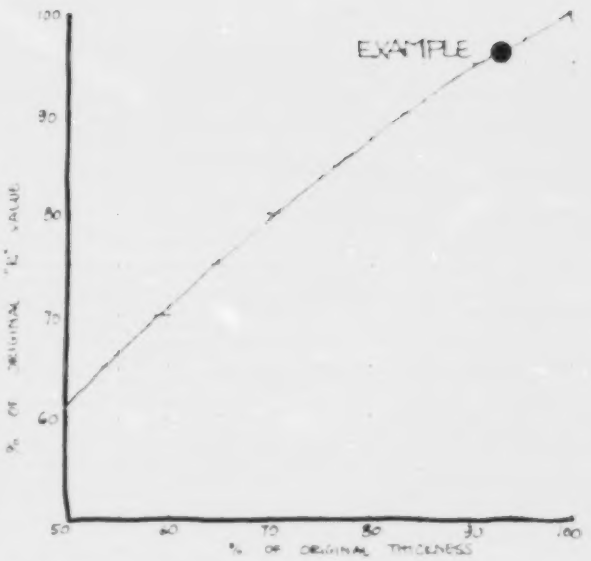


FIGURE 5·13 EFFECT OF COMPRESSING BATT INSULATION

5.3 Foundations

The builder is faced with a number of decisions regarding the insulation of foundations. The following criteria must be addressed in choosing the most appropriate system.

- type of insulation.
- amount of insulation required.
- depth of insulation — to the footings, to 1m below grade, etc.
- location of the insulation — interior vs. exterior.
- ease of installation and compatability with design and construction practices

In addition to economics, there are a number of practical considerations which must be taken into account. These are discussed following the recommendations below.

For further information builders should refer to the Canadian Home Builders' Association manual entitled "External Insulation of Basements".

5.3.1 Recommendations

- **In choosing a method of insulating foundations the builder should be guided by the compatibility of the method and/or the materials with his construction process.**
- **Project the foundation as little as possible above-grade.**
- **Unheated crawlspaces are generally not recommended.**
- **Heated crawlspaces should be treated by insulating the surrounding walls.**
- **Consider insulating below the floor slab when the foundation is in very wet soil , when the foundation is very shallow, or when the basement is to be used as a living area.**
- **When applying insulation to the exterior of the foundation walls, choose a material which is moisture resistant. Apply the insulation directly against the foundation wall to the house footing.**
- **When applying insulation to the interior of foundation walls, protect the insulation with dampproofing on the cold side of the insulation, an air/vapour barrier on the insulation's warm side, and an interior finish.**

5.3.2 General Notes for Foundation Design

Because the RSI value of the foundation wall is not usually uniform over the entire height, a single RSI value does not indicate its thermal effectiveness. Therefore, an annual heat loss factor is given in addition to the RSI value of the above-grade portion. This factor expresses the amount of energy in watt hours that will flow through a one metre wide vertical strip of wall, from sub-floor to floor slab. This factor takes into account heat flow during a one hour period with a one celsius degree difference between inside and outside air temperatures. It includes heat loss through:

- the joist header area,
- the above-grade portion of the foundation wall,
- the below-grade portion of the foundation wall.

The lower the heat loss factor, the more thermally effective the option.

The Guide recommends: a) dampproofing on the outside of foundation wall from footing to finished grade level, b) dampproofing on the inside of foundation wall from bottom of insulation to a height equivalent to finished grade level, and c) installing air/vapour barrier between the insulation and gypsum board.

5.3.3 Exterior-Applied Insulation

There are important advantages to placing insulation on the exterior of a unit masonry or concrete basement wall, even though extra care is required to protect it from mechanical damage during and after construction. When insulation is placed on the exterior of the wall, the wall can act as thermal mass and help to buffer temperature swings. Only insulating materials suitable for use in direct contact with the soil may be used.

It is easier to avoid thermal bridging at the floor joints and to use insulating sheathing so that the above-grade portion of the basement walls can be covered with an insulating layer (except when brick veneer is used). Applying insulation to the exterior of foundation walls offers the additional advantage of eliminating the need for interior framing.

Exterior applied insulation must be protected above-grade from both mechanical damage and ultraviolet radiation. This can be accomplished by covering it with 6.4 mm asbestos-cement board, with 12 mm cement parging applied to wire lath which is nailed through the insulation into the sill plate and foundation wall, or with preserved wood foundation grade plywood (Figure 5.14). Metal flashing can also be used as an alternative .

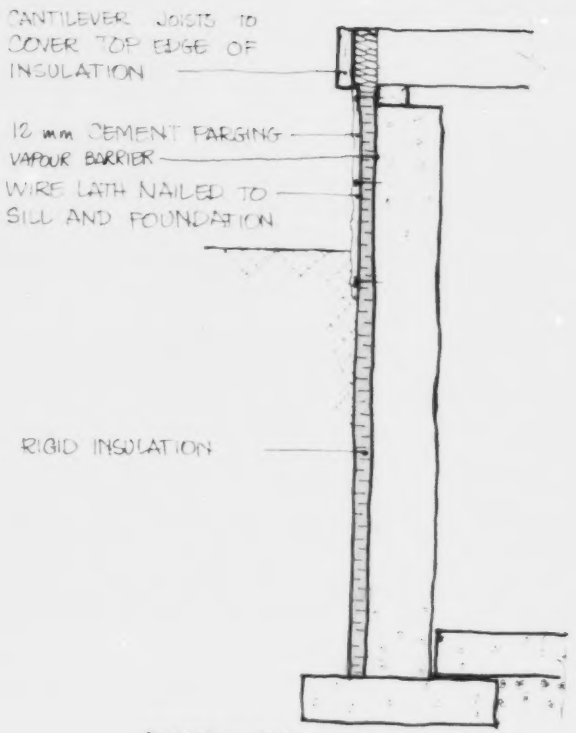

CANTILEVER JOISTS TO COVER TOP EDGE OF INSULATION
12 mm CEMENT PARGING
VAPOUR BARRIER
WIRE LATH NAILED TO SILL AND FOUNDATION
RIGID INSULATION

FIGURE 5.14 EXTERIOR APPLIED INSULATION

Note: For floor slab jointing details, see Figure 6-Perimeter Joint for Floor Slab – on page 17 of the CHBA "Guide to Construction of Cast-in-Place Concrete Basements for Housing and Small Buildings".

5.3.4 Interior-Applied Insulation

When applying insulation to the interior of foundation walls the builder must ensure that the insulation is protected in four ways —

- from condensation of interior humidity.
- from migration of exterior moisture through the wall.
- from fire.
- from mechanical damage.

Working upwards from the bottom of this list, it should be realized that virtually all insulating materials are rather soft and easily damaged. They should be protected by a durable interior finishing material in any area where human activities take place. Cellular plastic insulation must, by code, be protected from fire. The concern here is not just that they are flammable but that they tend to contribute to the rapid spread of fire.

Even the best basements are not completely watertight. There is always the risk of water migrating through the wall and affecting the insulation. The cellular plastics generally have enough moisture resistance that no further protection is required. Other types, and any wood applied to the inside of foundation walls, should be protected by dampproofing the inside surface of the wall. This can consist of bituminous coatings, polyethylene sheets or permeable asphalt — impregnated felt building paper.

The dampproofing should not be applied above the finished exterior grade level in order to facilitate dissipation of any moisture which does accumulate. Where wood is in direct contact with the masonry, a layer of dampproofing must be installed to prevent capillary moisture movement into the wood. An alternative would involve the use of pressure treated wood.

Like any insulated building element, the foundation wall requires the protection of an effective air/vapour barrier. Insulation materials with low permeability, such as the cellular plastics, provide their own resistance to vapour diffusion and do not require a vapour barrier if the interior finish is applied so that its joints do not coincide with the insulation joints, and it fits tightly to the insulation. Otherwise the methods and principles illustrated in Subsection 5.1 generally apply. A few added precautions can be given.

- All edges of porous insulation should butt against solid blocking to discourage air circulation through the insulation.
- Place a bead of sealant beneath all strapping at the base of the insulation or caulk along the edge of the strapping against the wall to discourage air movement behind the insulation.
- Where rigid insulation is glued to the wall, apply the adhesive in a grid of beads rather than as daubs so that each bead acts as a further barrier to air movement. Where a protein-based adhesive is used it should be the type with preservative added to discourage the growth of fungi and other micro-organisms.

See also Figures 5.15 and 5.16.

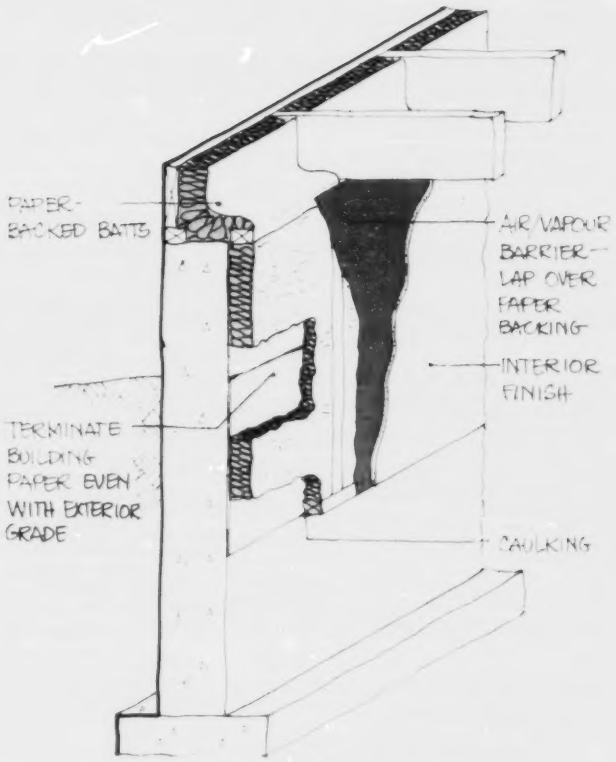


FIGURE 5.15 INTERIOR APPLIED INSULATION

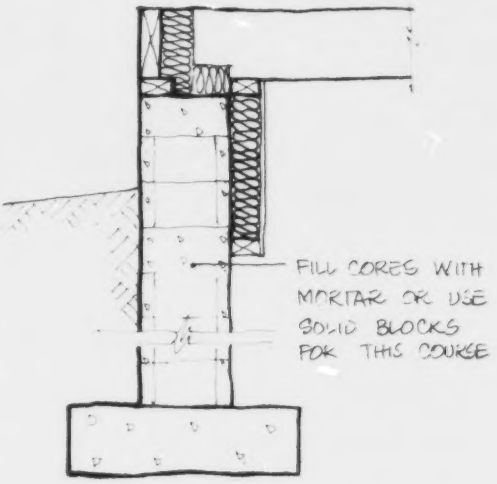


FIGURE 5.16 INSULATION OF HOLLOW MASONRY WALLS.

CONVECTION CURRENTS IN THE CORES OF HOLLOW MASONRY WALLS CAN GREATLY INCREASE HEAT LOSS. THIS EFFECT CAN BE REDUCED BY INSULATING FULL HEIGHT OR BY FILLING THE CORES EVEN WITH THE BOTTOM OF THE INSULATION.

5.3.5. Amount of Projection Above-Grade

It is generally more difficult and costly to insulate foundation walls than frame walls. Thus they will tend to have lower thermal resistance.

The above-grade portion of the foundation wall loses more heat than the below-grade portion because of its exposure to colder temperatures. Unless insulated to the same levels as the frame walls above, it makes sense to keep the height of this above-grade portion to a minimum. It should be noted that if the basement is too low in the ground, it will be necessary to resort to window wells or eliminate windows entirely, where codes permit.

Where the house design favours a higher basement, such as with split-entry houses, the foundation itself should be terminated slightly above-grade and the wall continued with frame construction.

5.3.6 Preserved Wood Foundations

Preserved wood foundations can offer a number of advantages including ease of installation and provision of a warmer foundation. CSA has developed standards for the design and construction of preserved wood foundations which should be followed by any builder considering this construction technique. Only wood products meeting this standard are recommended for use in wood foundations. The Canadian Wood Council provides data file publications on this topic including detailed drawings. Builders considering this type of foundation construction should refer to CSA Standard CAN3-S406-M83 "Construction of Preserved Wood Foundations", as well as the Canadian Wood Council's manual, Preserved Wood Foundations. Figure 5.17 shows a sample detail.

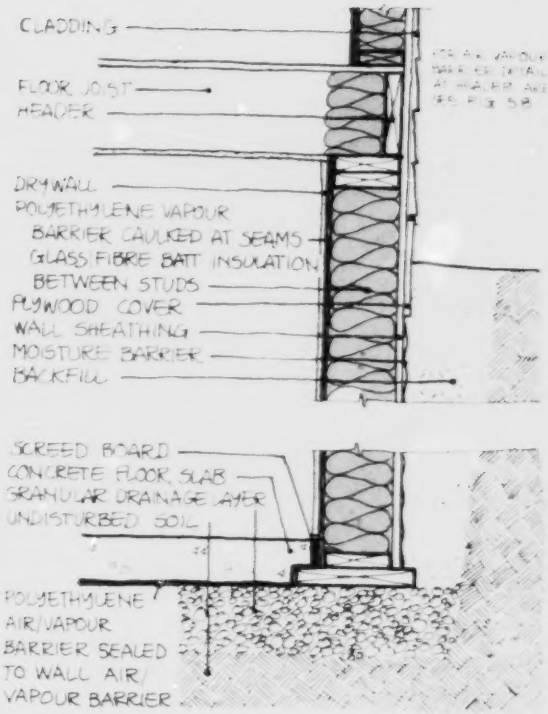


FIGURE 5·17 PRESERVED WOOD FOUNDATION
NOTE: ALL WOOD TO BE MARKED C.S.A. CERTIFIED 0322 P.W.F.

5.3.7 Insulation of Crawl Spaces

There are two basic approaches to insulating crawl spaces — insulation can be installed between the floor joists, or the walls surrounding the crawl space can be insulated. For heated crawl spaces, the latter is recommended since it provides a warm crawl space where ducts and piping can be routed without having to be insulated. There is usually less area to insulate with this approach.

Some authorities may take the arbitrary view that unless heat is deliberately supplied to the crawl space it constitutes unheated space and therefore the floor separating it from the house must be insulated. Such a view can be countered by pointing out that the total heat loss from inside the house will not be increased by insulating the crawl space walls. Generally, to avoid moisture and related problems, unheated crawlspaces are not recommended.

Vents with insulated, weatherstripped covers should be provided so that the crawl space can be ventilated in summer (Figure 5.18). Home buyers should be advised to open these for summer and close them in winter. Alternatively, if the crawl space is used as an insulated warm air plenum, the furnace fan can be left on in the summer to provide ventilation and vents will not be required.

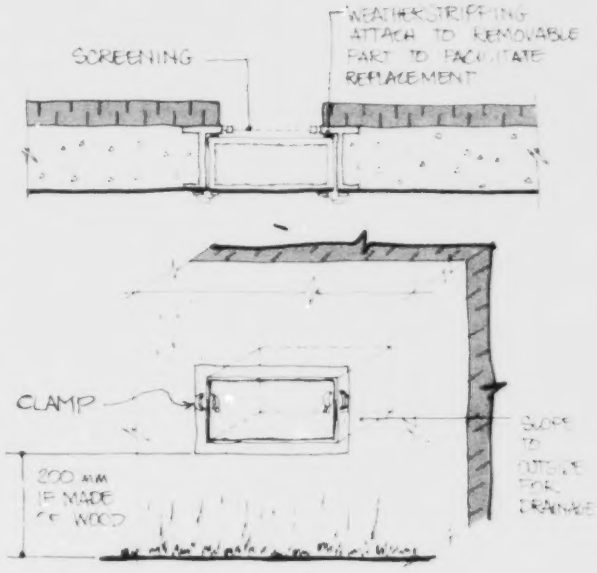


FIGURE 5·18 CRAWL SPACE VENTS AND COVERS
TOTAL VENT AREA = 1/300 OF CRAWL SPACE FLOOR AREA

A thickness of insulation and a level below grade judged economical for basements will also be economical for crawl spaces. There is the additional option that the portion which would have been placed below-grade can simply be laid along the floor of the crawl space (Figure 5.19). It should be noted, however that this method cuts off flow of heat to the footings and should only be used where the footings are below the frost line.

5.3.8. Insulating Slabs-on-Grade

The amount of insulation used on basement walls can serve as a guideline for insulating around the perimeter of a slab-on-grade. Figure 5.20 shows perimeter slab insulation techniques.

5.3.9 Wet Soils

It has been found that where soil is very wet, and especially where there is water flowing through the soil, the soil not only fails to provide any insulation, but it can actually act as a heat drain. On wet sites, therefore, the savings from any given insulation option could be larger, as much as 25% higher, than the savings provided by a similar amount of insulation in dry soil. The economic insulation level will therefore be correspondingly higher. Unfortunately, the current state of knowledge of the dynamics of heat loss in wet soils, and the difficulty of predicting the presence of waterflow at any one particular site makes it difficult to provide more specific guidance in this situation.

5.3.10 Insulating Basement Floors

At normal basement depths and where the soil is dry, below slab insulation is unlikely to be worthwhile. It may be economical to insulate the floor of shallow basements and those on wet sites, however, or where improved comfort levels are required. Specifically, if the basement is to be used as living space, below slab insulation will result in a more comfortable floor temperature.

Where it is effective to insulate a basement floor it is generally more effective to insulate a one metre strip around the perimeter wall with a higher R value than the centre area. For shallow basements follow the guide given for crawl spaces.

5.3.11 Foundation Insulation And Brick Veneer

In cases where a brick veneer is used for the exterior of the building, it is important to design a thermal break into the area where the veneer and foundation wall meet. Without the proper design considerations, this area can become a thermal weak point in an otherwise well insulated shell of a building.

Figures 5.21 and 5.22 show veneer and foundation wall details for exterior and interior insulated basements respectively.

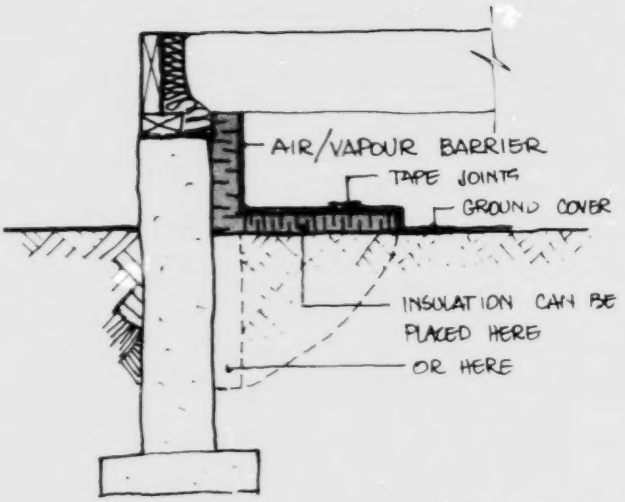


FIGURE 5.19 INSULATION OF CRAWL SPACES

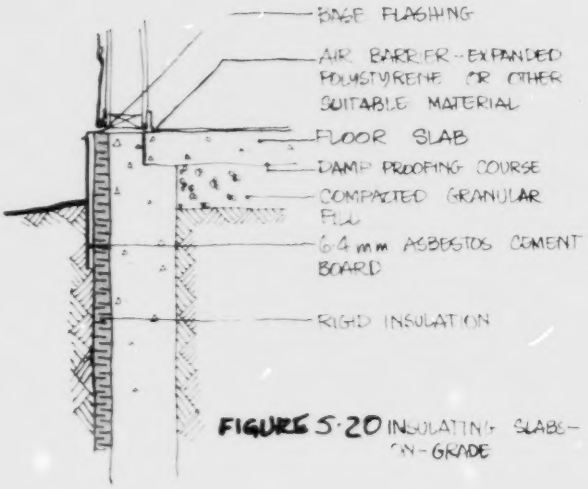


FIGURE 5.20 INSULATING SLABS-ON-GRADE

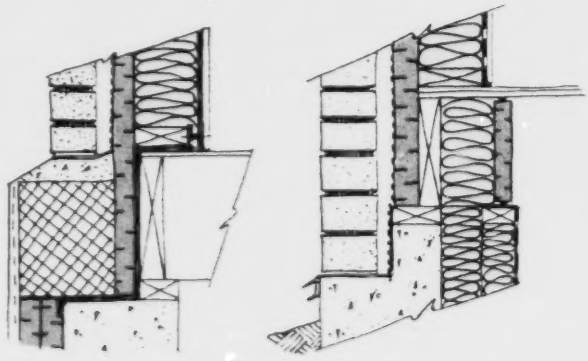


FIGURE 5.21/5.22 INTERIOR AND EXTERIOR INSULATED BASEMENTS

5.4 Floors

Floors separating heated space from unheated space or the outdoors must be insulated. This condition commonly occurs over unheated garages and unheated crawl spaces and at floor overhangs.

5.4.1. Recommendations

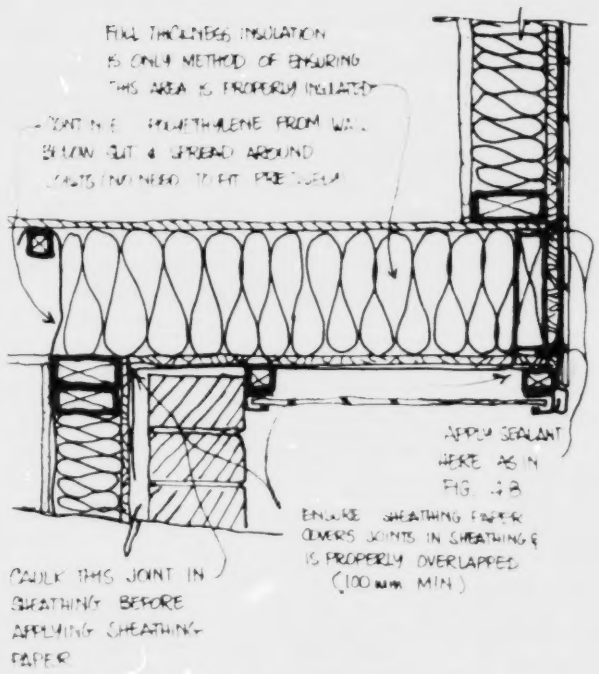
- Insulate floors above garages even if the garage is intended to be heated.
- Use insulation to the full thickness of the joists in floors.
- Apply sheathing and sheathing paper on floor overhangs with great care in order to achieve an effective air barrier.

5.4.2. General Notes

Even where a garage is provided with heating it is a good idea to insulate the structure separating it from the house to minimize heat loss when garage doors are left open . This is not specifically required by the Ontario Building Code but it is prescribed in CMHC Builders' Bulletin No. 267.

Cold floors are a common homeowner complaint. Failure to insulate the floor perimeter properly and to provide an effective air barrier are the normal causes of discomfort. Full thickness insulation combined with the air barrier practices shown in Figure 5.23 will go far towards eliminating these problems. The addition of a permeable air barrier material on the underside of the floor joists can minimize cold air entering the insulated cavities. Figure 5.24 provides additional details.

Another defence against cold floors is to ensure, through proper design of the heating system, that heated air is circulated across the floor (see Section 6). Ensure adequate insulation below heating ducts to prevent cooling of hot air.


FULL THICKNESS INSULATION IS ONLY METHOD OF ENSURING THIS AREA IS PROPERLY INSULATED
CUT TO FIT POLYETHYLENE FROM WALL BELOW CUT & SPREAD AROUND JOISTS (NO NEED TO FIT PRECISELY)
APPLY SEALANT HERE AS IN FIG 4.8
ENSURE SHEATHING PAPER COVERS JOINTS IN SHEATHING & IS PROPERLY OVERLAPPED (100 mm MIN.)
CAULK THIS JOINT IN SHEATHING BEFORE APPLYING SHEATHING PAPER

NOTE ACHIEVING A CONTINUOUS AIR BARRIER AS SHOWN IN FIG 4.8 IS VERY DIFFICULT AT THIS LOCATION AND A GREAT DEAL OF CARE MUST BE TAKEN IN APPLYING THE SHEATHING AND THE SHEATHING PAPER TO THE UNDERSIDE OF THE OVERHANG. IF THIS IS NOT DONE PROPERLY, FLOOR MAY BE COLD DESPITE FULL THICKNESS INSULATION DUE TO AIR INFILTRATION

FIGURE 5-23 TREATMENT OF FLOOR OVERHANG

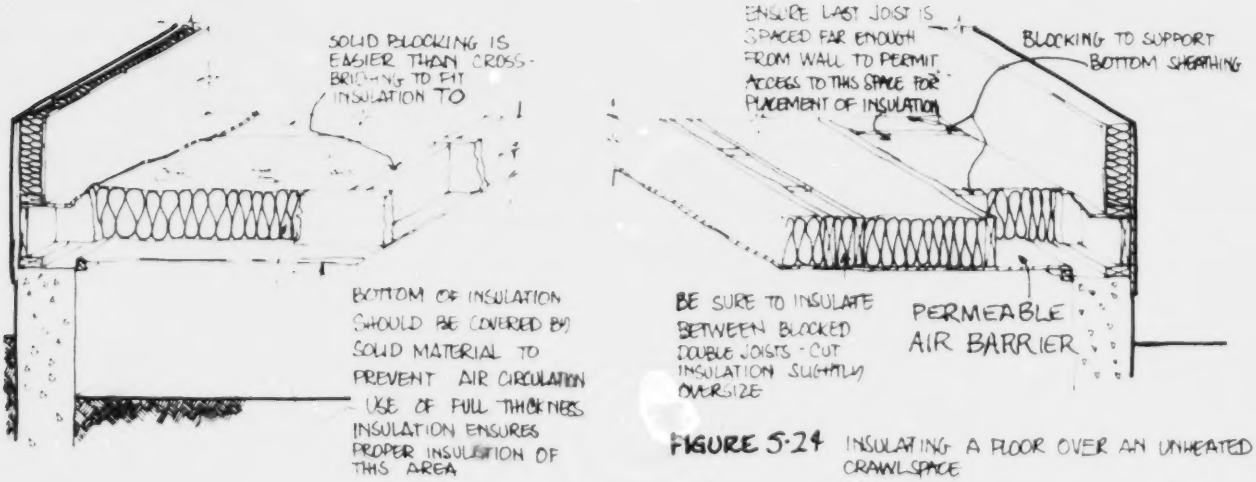

SOLID BLOCKING IS EASIER THAN CROSS-BRIDGING TO FIT INSULATION TO
BOTTOM OF INSULATION SHOULD BE COVERED BY SOLID MATERIAL TO PREVENT AIR CIRCULATION
USE OF FULL THICKNESS INSULATION ENSURES PROPER INSULATION OF THIS AREA
ENSURE LAST JOIST IS SPACED FAR ENOUGH FROM WALL TO PERMIT ACCESS TO THIS SPACE FOR PLACEMENT OF INSULATION
BLOCKING TO SUPPORT BOTTOM SHEATHING
BE SURE TO INSULATE BETWEEN BLOCKED DOUBLE JOISTS - CUT INSULATION SLIGHTLY OVERSIZE
PERMEABLE AIR BARRIER

FIGURE 5-24 INSULATING A FLOOR OVER AN UNHEATED CRAWLSPACE

5.5 Walls

The Ontario Building Code prescribes the use of RSI 2.11 insulation in walls. CMHC Builders' Bulletin No. 267 accomplishes much of the same effect by prescribing an overall RSI value of 2.5 which can be achieved by combining RSI 2.11 batts with common cladding, sheathing and finish materials. "Measures for Energy Conservation in New Buildings" prescribes higher RSI values than can be achieved with normal 38 x 89 stud walls. Many builders are now building with 38 x 140 studs or are applying an insulating sheathing to the exterior of the walls. The following notes review various ways of achieving these higher RSI values.

5.5.1. Recommendations

- In choosing a method of achieving higher RSI values for walls, the buider should be guided by the compatibility of the method and materials with his construction process.
- Use the widest framing spacing permissible (600 mm) in order to reduce the thermal bridging effect.
- Use corner and intersection details which reduce the amount of framing and allow it to be replaced by insulation.

There are basically four types of wood frame wall systems which are capable of achieving higher RSI values than the code minimum:

- single stud,
- strapped wall,
- double wall,
- standoff or expanded truss.

No one method is right for all buiders since each has its particular advantages. Figures 5.26, 5.27, 5.28 and 5.29 provide details of the construction of these four types of walls.

5.5.2 Higher Density Insulation Batts

RSI 2.47/89 mm batts suitable for installation in 38 x 89 stud walls have recently been made available. Although these batts are more expensive, they provide an extra RSI 0.36 with no other change in construction practices. Of course the overall maximum RSI value of the wall that can be achieved with this method is limited to about RSI 2.9 unless these batts are used in combination with rigid insulation.

5.5.3 Deeper Studs

The use of 38 x 140 studs permits the installation of RSI 3.5 batts although the resulting compression of the batts reduces their RSI value to 3.36.

5.5.4 Rigid Insulation in Place of Sheathing

Rigid insulation materials can be installed in place of conventional sheathing materials. These higher insulating materials do not provide the structural strength of conventional sheathings and must be complemented by diagonal bracing of the framing. While the insulating sheathings available on the market vary in their insulation value and properties several considerations will need to be adressed by the builder.

- the majority of the insulated sheathings are less able to withstand the rugged handling associated with platform frame construction, especially when the walls are prefabricated.

- installation of some siding materials over the less rigid materials may result in poor results. Care is required to avoid irregularities in the finished siding.

The benefits of applying an insulating sheathing are significant. The continuous nature of the insulating blanket around the house over the framing, reduces heat loss and provides a more uniform RSI value over the whole wall. The most common insulated sheathings are listed in Table 5.1.

5.5.5. Other Factors

One consideration that applies to methods in Subsections 5.5.3 and 5.5.4, is that both increase the thickness of the wall to some degree. This obviously entails some extra cost for such things as:

- longer roof trusses,

- more cladding,

- deeper window and door frames, or,

- reduced floor area.

The extra cost is difficult to measure. However, builders may want to keep this in mind when weighing the relative merits of these methods.

Where 400 mm spacing of 38 x 89 studs is required, such as for the first storey wall of a 2-storey house, the relative economics of the 38 x 140 stud options will be enhanced. The use of 600 mm spacing is recommended, where permitted, since it results in an appreciable increase in the overall thermal resistance of a wall.

Choice of the proper framing details at corners and intersections can also reduce the amount of wood in the wall and increase the amount of insulation. Suggested details are shown in Figure 5.25.

Table 5.1 Rigid Insulation Materials

Rigid Insulation	Advantages	Disadvantages
Type I&II Expanded Polystyrene (Beadboard)	– rigid – permeable*	– low strength and rigidity
Phenolic Foam Board	– fairly rigid due to paper facings – high permeability*	– relatively high cost
Extruded Polystyrene	– high strength – high RSI value	– low permeability* – relatively high cost
Foil-Faced Isocyanurate Foam Board	– highest RSI value – fairly rigid due to foil facings	– lowest permeability*
Semi-Rigid Glass Fibre Board	– high permeability* – may enhance air-tightness by fitting snugly to plates, headers etc.	– low rigidity can be crushed

*Note: There is some risk of condensation problems arising from the placement of low permeability materials on the outside of walls. However no documented cases of such problems have come to light and use of the air vapour barrier installation practices shown in Subsection 5.1 should minimize any such risk.

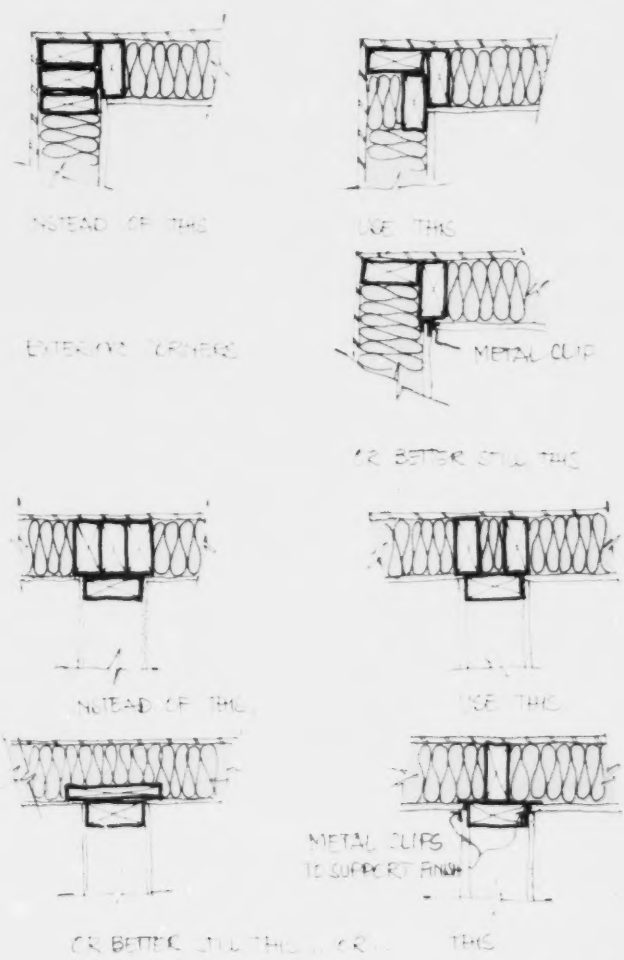


FIGURE 5.25
INTERSECTION AND CORNER DETAILS

5.5.6 Examples

Single Stud Wall

The conventional single stud wall (see Figure 5.26) provides many opportunities for upgrading which will increase the RSI value of the wall. As mentioned in Sections 5.5.2, 5.5.3, and 5.5.4, the following options can be used either singly or in combination.

- 38 x 140 studs and RSI 3.5 insulation
- Insulated sheathing (exterior or interior)
- High density insulation (RSI 2.46)

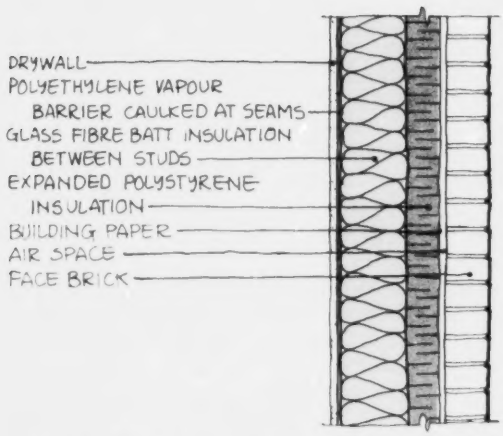


FIGURE 5.26 SINGLE STUD WALL

Strapped Wall

The strapped wall (Figure 5.27) not only allows for the opportunity to increase the RSI value for the wall with added insulation in the extra wall cavity but it also reduces framing losses due to thermal bridging. The vapour barrier can be protected against accidental puncture during drywall installation by being inside the wall. Wiring and plumbing can then be run in the strapped cavity without having to penetrate the air/vapour barrier. As was mentioned earlier, no more than one-third of the RSI value of the insulation should be on the warm side of the vapour barrier, or condensation within the insulation can occur.

The following stud and strapping material variations can be used either singly or in combination:

- 38 x 89 or 38 x 140 studs,
- 38 x 38 or 38 x 64 strapping,
- exterior insulated sheathing,
- higher density insulation.

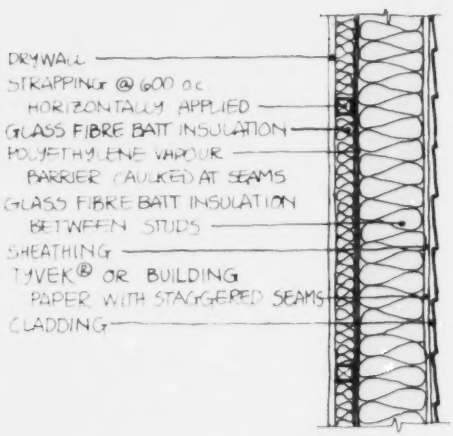

DRYWALL
STRAPPING @ 600 o.c. HORIZONTALLY APPLIED
GLASS FIBRE BATT INSULATION
POLYETHYLENE VAPOUR BARRIER CAULKED AT SEAMS
GLASS FIBRE BATT INSULATION BETWEEN STUDS
SHEATHING
TYVEK® OR BUILDING PAPER WITH STAGGERED SEAMS
CLADDING

FIGURE 5.27 STRAPPED WALL

Double Stud Wall System

This system allows for a significantly larger wall cavity with the possibility of very high levels of insulation. The system minimizes thermal bridging from the interior to the exterior (Figure 5.28).

The following variations can be used, either singly or in combination:

- 38 x 89 studs or 38 x 89 with 38 x 64 studs;
- interior or exterior wall can be load bearing;
- higher density insulation;
- air/vapour barrier can be placed on the inside face of the exterior wall; the outside face of the interior wall, or, the inside face of the interior wall;

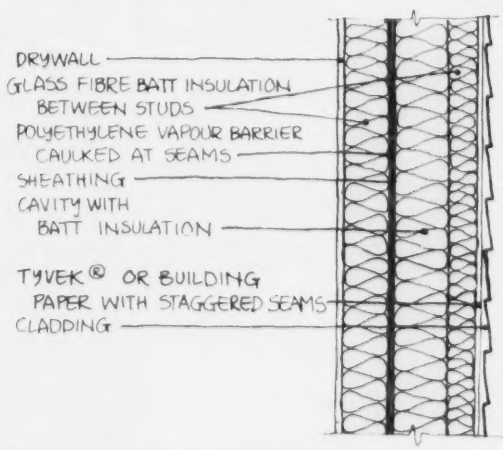


FIGURE 5.28 DOUBLE STUD WALL SYSTEM

- insulating sheathing can be placed on the outside of the inside wall or on the outside of the outer wall;
- insulation can be placed in the space between the stud walls;
- the amount of insulation placed in the space between the stud walls is determined by the amount of space provided.

Stand-off or Truss Wall

The stand-off or truss wall allows for both a thicker wall assembly, and an easier installation of the air barrier. The truss thickness can be varied to accommodate the desired level of insulation. The house is conventionally framed and sheathed, with the exterior wall hung on the outside of the sheathing. This is shown in figure 5.29.

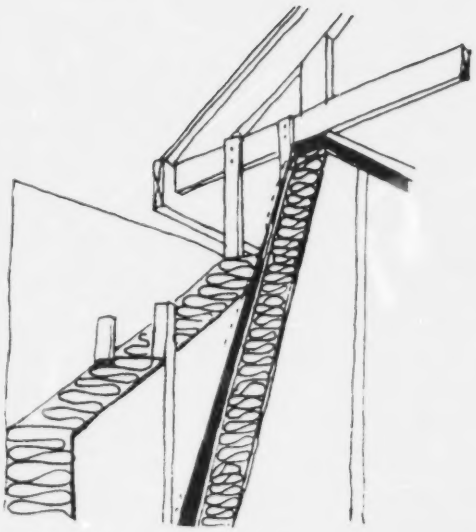


FIGURE 5·29 TRUSS WALL

5.6 Attic Spaces

Builders can make attic-type roofs more energy efficient simply by increasing the amount of insulation in the ceiling joists. Additional care must be taken to ensure proper ventilation.

5.6.1 Recommendations

- Order loose fill insulation by weight or RSI value rather than thickness.
- Increase ceiling gypsumboard thickness when thick water-based textured finishes are used.
- Insulate the ceiling before any moisture producing operations are undertaken during winter construction.
- Ventilate houses during winter construction to carry away the moisture produced by construction processes and the use of gas-fired heaters.
- Keep soffit vents open.
- Use baffles at eaves to prevent insulation from being displaced or penetrated by the wind.

5.6.2 Insulation and Application Factors

The importance of an effective air and vapour barrier at the upper extremities of the house has been stressed. This is especially true with respect to the house ceiling. Attic insulation levels can be upgraded without major alterations to conventional construction practices. As a general rule attic insulation is inexpensive .

To allow higher levels of insulation at the eaves of the house — above the top plate— the builder can consider the use of alternative truss designs (high heel or cantilevered truss configurations). Where higher levels of insulation are required in flat roofs or cathedral ceilings, alternative framing might involve the use of scissor truss or plywood I beam configurations.

Certain types of loose fill insulation, including cellulose fibre and mineral wool, are subject to settling after installation if they are not installed properly. For this reason it is best to specify such materials by weight or RSI value rather than thickness. For example, CMHC requires that cellulose fibre manufacturers print a table such as Table 5.2 on their bags.

These figures can be found in CMHC's "Acceptable Building Materials System and Equipment Manual".

There has been some concern expressed in recent years that the added weight of the insulation levels now being considered can lead to sagging of gypsumboard ceilings. Although this is not entirely without basis, recent studies have indicated that the problem is caused principally by dampening of the gypsum board due to some combination of the following conditions:

- application of thick, water-based textured finishes;
- high humidity during winter construction due to rapid drying of building materials in tightly closed houses;
- vapour diffusing through the board and condensing on the vapour barrier prior to installation of the insulation during winter construction.

If any of the above conditions cause the board to sag, it will sag even more with added insulation on it. The primary way of avoiding this problem is not to decrease the amount of insulation but to use stronger gypsumboard (16 mm instead of 13 mm) or avoid the above conditions by:

- not using thick, water-based, textured finishes;
- providing better ventilation during construction;
- installing insulation before undertaking moisture-producing operations, such as pouring the basement floor slab or applying water-based finishes.

5.6.3 Ventilation of Attic Spaces

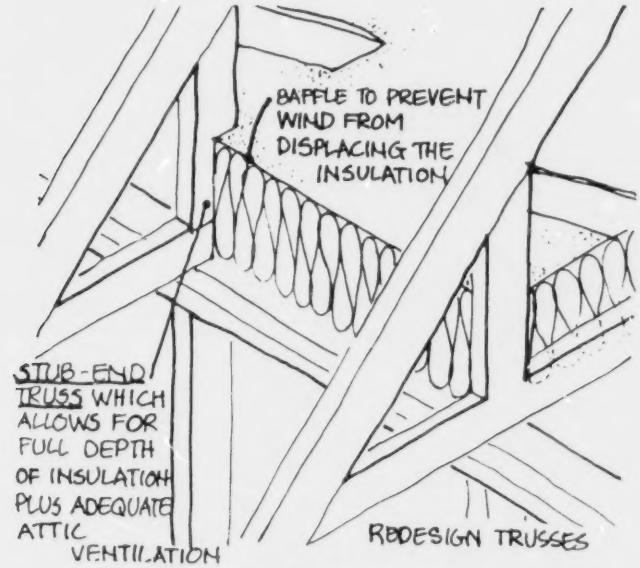
Roof space ventilation is the second line of defence against attic condensation problems (the first being the creation of a good ceiling air/vapour barrier). It is easily accomplished in attic-type roofs. The vent area specified by codes is normally adequate (1/300 of ceiling area for most roofs, 1/150 of ceiling area for low slope roofs). It should be distributed evenly around the building. When practical, half the vent area should be located in the soffits and the other half high on the roof (gable, roof or ridge vents) in order to take advantage of stack effect created by solar heating of the attic. The construction of low and high vents may also help in summer cooling. The only precaution that requires mention is the need to avoid rendering soffit vents useless by blocking the area between the wall top plate and the roof sheathing with insulation. A number of methods of avoiding this are shown in Figures 5.30 and 5.31 and 5.32.

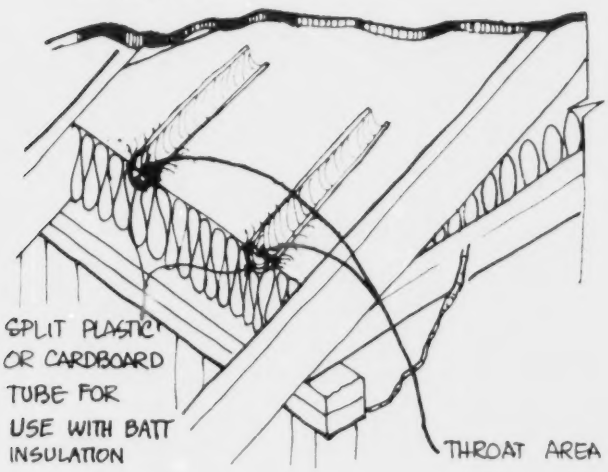
For further discussion of roof space ventilation see Subsection 5.7.2.

Table 5.2 Thermal Resistance by Thickness and Weight of Cellulose Fibre

Thermal Resistance RSI	Thickness (On Day of Application) mm	Settled mm	Weight per Unit Area kg sq m
1.0	(46)	39	1.5
2.0	(93)	78	3.0
3.0	(142)	119	4.6
4.0	(193)	161	6.2
5.0	(242)	202	7.8
6.0	(291)	243	9.3
7.0	(340)	284	10.9

(The values in this table are not necessarily typical since they will vary from one manufacturer to another.)


BAFFLE TO PREVENT WIND FROM DISPLACING THE INSULATION
STUB-END TRUSS WHICH ALLOWS FOR FULL DEPTH OF INSULATION PLUS ADEQUATE ATTIC VENTILATION
REDESIGN TRUSSES



NOTE: TOTAL THROAT AREA SHOULD AT LEAST EQUAL TOTAL SOFFIT VENT AREA.

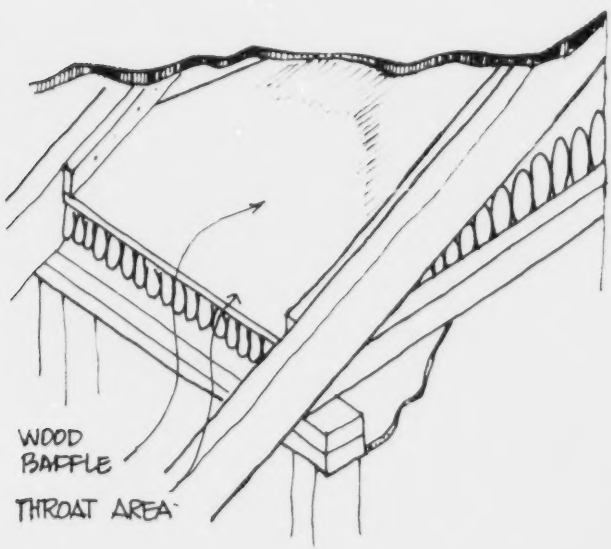


FIGURE 5·30 VARIOUS METHODS OF AVOIDING RESTRICTION OF ROOF SPACE VENTILATION WITH DEEP INSULATION.

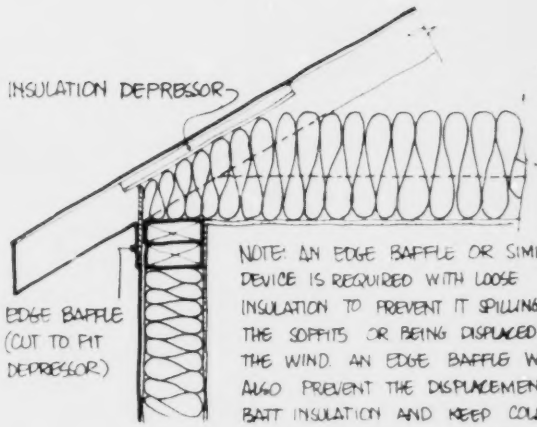

INSULATION DEPRESSOR
EDGE BAFFLE (CUT TO FIT DEPRESSOR)
NOTE: AN EDGE BAFFLE OR SIMILAR DEVICE IS REQUIRED WITH LOOSE INSULATION TO PREVENT IT SPILLING INTO THE SOFFITS OR BEING DISPLACED BY THE WIND. AN EDGE BAFFLE WILL ALSO PREVENT THE DISPLACEMENT OF BATT INSULATION AND KEEP COLD AIR FROM PENETRATING THE EXPOSED EDGE OF THE BATTS.

FIGURE 5·31 EDGE BAFFLE

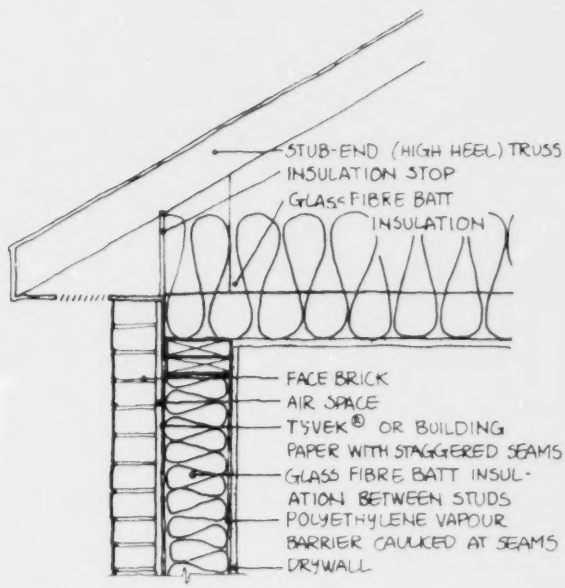


FIGURE 5·32 STUB END OR HIGH HEEL TRUSS

5.7 Flat and Cathedral Roofs

Insulating this type of roof is much more difficult, the problem being to accommodate the required thickness of insulation and still leave enough room for ventilation between the insulation and the roof deck.

5.7.1 Recommendations

- Avoid the use of flat and cathedral roofs if possible.
- Where a flat or cathedral roof is required, use truss framing if possible.

5.7.2 Ventilation

In Subsection 5.6 it was stated that the ventilation of the roof space is not as important as a good air/vapour barrier in preventing condensation problems. But since it is probably impossible to create a perfect air/vapour barrier, ventilation should not be overlooked.

The role of roof space ventilation is not fully understood at this time, even by building scientists. It is commonly believed that its main purpose is to dissipate water vapour entering the roof space through imperfections in the air/vapour barrier. How effective cold winter air (which is already at 80% or 90% relative humidity) would be in performing this function is subject to doubt. It should be reiterated that an effective air and vapour barrier will minimize the entry of water vapour into the roof space — downplaying the need for ventilation.

It may be that the most important function of roof space ventilation is the drying out of winter condensation by the warmer spring and summer air. Without such ventilation, the moisture can remain in the roof space into the summer, when the combination of high temperature and moisture creates ideal conditions for the growth of decay organisms.

5.7.3 Methods of Insulation

There are three methods of insulating flat and cathedral type roofs:

- use deep joists and cross-purlins to create a ventilation space above the insulation;
- use parallel chord trusses to create a ventilation space above the insulation;
- use rigid insulation applied to the top of the roof sheathing or rigid insulation applied on top of the roof membrane (inverted roof).

The advantages and disadvantages of these methods are discussed below:

Cross-purlins

The Ontario Building Code requires a minimum of 38 x 38 mm cross purlins to be applied across the top of the roof joists where the roof does not incorporate an attic space, and the top of the insulation shall be at least 25 mm below the top of the roof joists. This method has the advantage of using familiar materials and carpentry . Care must be taken that the batt insulation installed from below is not pushed up tight against the cross purlins.

Parallel Chord and Scissor Trusses

The use of parallel cord trusses (either flat or sloping) may be a more economical method of increasing the depth of the roof when erection time is taken into consideration.

The open nature of trusses also allows cross-ventilation between truss spaces, which is desirable since moisture escaping through an imperfection in the air/vapour barrier can be dissipated over a wider area. In order to be economical, however, trusses require a significantly greater depth than joists for the same span, and this will not always have an acceptable appearance. For cathedral ceilings, scissor trusses rather than parallel chord trusses may be used (Figure 5.33).

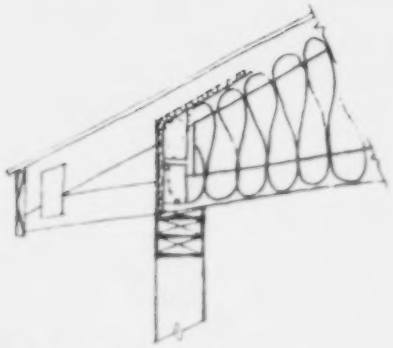


FIGURE 5·33 SCISSOR TRUSS

Rigid Insulation

Placing the insulation on top of the roof sheathing eliminates a cold cavity within the roof and thus greatly reduces the risk of condensation. But rigid insulation materials are generally expensive and may have to be put on in mulitple layers to achieve even the minimum Ontario Building Code RSI value. A variation of this method is the so-called "Inverted roof" (Figure 5.34) in which the roofing membrane is placed directly on the roof sheathing and the insulation is placed on top of it, rather than the other way around. This has the advantage of protecting the membrane from ultraviolet radiation and large temperature variations. However, good drainage is essential to avoid floating the insulation. Only insulations which are approved for placement on top of the roof membrane should be used for this method. An example is rigid board glass fibre designed to support limited traffic during application.

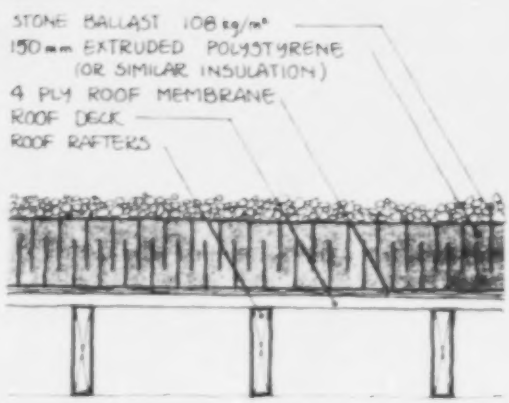


FIGURE 5·34 INVERTED ROOF SYSTEM

5.8 Windows

General opinions on windows have varied sharply in recent years. Before the cost of energy became a concern, large amounts of glass area were seen as desirable; the "picture window" was something no house could be without. With the coming of the 'energy crisis' the window very quickly became regarded as a gross energy waster that must be kept to an absolute minimum. Only recently has there been any general recognition that windows can also be energy gainers when the sun is shining on them. This positive, energy-gaining aspect of windows is dealt with in Subsection 6.6.4 on Enhanced Passive Solar Systems. This subsection will deal only with energy losses through windows and steps the builder can take to minimize them.

5.8.1 Recommendations

- All windows, including glazed doors and sidelights, should be double glazed with a 12.5 mm air space.
- Triple glazing should be considered in colder areas (more than, say, 6000 degree days C) with a minimum of 12.5 mm air space.
- If windows with metal frames are used, be sure that the frame is thermally broken (inner and outer portions of the frame separated by a material with low heat conductivity).

- In comparing costs of sealed double or triple glazing, bear in mind that the spacing between the panes has a significant effect on performance.

- Be cautious when considering the use of insulating interior shutters or blinds because those with poor seals will allow condensation build up between the inside surface of the glass and the shutter or blind.

- Choose windows whose resistance to air leakage is known to be good.

- Install windows in a manner which does not destroy their airtightness and which creates an insulated airtight window/wall joint.

5.8.2 Introduction

Energy is lost through a window in three ways:

- Heat flow through the window and frame.

- Air leakage through the many joints in the window itself.

- Air leakage through the joint between the window and the wall.

There are three actions a builder can take to reduce these losses:

- Choose windows with higher thermal resistance.

- Choose windows with a demonstrated resistance to air leakage.

- Install the windows in a manner which does not reduce their leakage resistance and which minimizes leakage through the window/wall joint.

Each of these actions is discussed in some detail in the following sections.

5.8.3. Increased Thermal Resistance

The most obvious method of increasing the thermal resistance of windows is to add more layers of glazing. Double glazing (either storm sash or sealed double glazing) has come to be regarded as standard practice in Canada. It is prescribed by the Ontario Building Code and, for most parts of Canada, by CMHC Builders' Bulleting No. 267.

Triple and even quadruple glazing are now available in many areas.

An important factor to keep in mind regarding sealed double or triple glazing is that the space between the panes has a significant effect on the thermal resistance of the unit. The optimum spacing is about 16 mm, with performance falling off rapidly for spacing smaller than 12.5 mm but falling off only moderately for larger spacing.

Metal window frames should incorporate thermal breaks, not only to reduce heat loss but also to avoid serious interior condensation and frosting.

New Window Technology

Recently there have been a number of exciting developments in window technology that are resulting in window products that are lighter and much more energy efficient. One feature common to all windows is that they are all much more expensive than traditional window designs. Some of these new technologies are briefly discussed below. For more information contact your local supplier.

Low "E" Glass

In a typical window about half of the total heat loss occurs as a result of radiant losses. Windows can be treated with a special low E (emissivity) coating that readily admits long wave radiation (light) but will also reflect short wave radiation (heat) back into the house. As a result these windows can retain heat inside during the winter and reflect heat gain out during the summer. This coating can be applied directly to the glass or suspended between glass panes on a plastic film.

Where a typical double paned window would have a RSI value of 0.35, the RSI value of windows with Low E coatings can range from RSI .44 to .76.

One disadvantage of these types of windows is that the ability to reflect long wave radiation means that much of the potential for solar heat gain is also lost.

Anti-Reflective Films

These types of windows incorporate a thin plastic film suspended between two panes of glass. This innovation is basically a improvement of the triple glazed window. The plastic film has virtually the same RSI value as a extra pane of glass, yet it is a fraction of the weight. The film is also less reflective than ordinary glass so that solar gain can be enhanced.

Gas Filled Windows

In these type of windows a gas heavier than air is injected between the panes of glass of a well sealed double pained window unit. The glass is also often coated with a Low E coating. Gases such as argon, sulphur hexafluoride, and carbon dioxide are used.

The gas filling in the window combined with the low E coating will provide a double pane unit providing a RSI value up to 0.59 (compared to 0.35 for traditional window units.

Though not presently available in Canada these type of window units are widely used in parts of Europe.

Windows incorporating a combination of low E coatings, gas fill and insulated edge spacers between glazing layers are currently being tested which demonstrate RSI values in excess of 1.0.

Interior Shutters or Blinds

Because such a device will make the window surface much colder than it would normally be, the shutter or blind must be tightly sealed to prevent humid household air circulating behind it.

The seal should be much more effective than the seal on the inner pane of double windows, since the shutter will cut off much more heat flow than will an inner pane. Without this seal, experience has shown condensation can build up (Figure 5.35).

Internal insulating devices also create increased potential for thermal breakage of the windows as they warm up after the devices are retracted.

Exterior Shutters

The obvious problem here is to provide an operating mechanism that will remain operable despite long periods of exposure to severe weather conditions. The shutter must also be well sealed against the window in spite of the accumulation of snow and ice. If the shutter cannot close tightly, circulation of cold outside air behind it will greatly reduce its effectiveness.

INTERIOR INSULATING SHUTTERS OR BLINDS MUST BE WELL SEALED AROUND THEIR PERIMETERS TO PREVENT CIRCULATION OF WARM, MOIST INTERIOR AIR WITH RESULTING FROST BUILD UP.

FIGURE 5·35 INTERIOR INSULATING SHUTTER

5.8.4 Resistance to Air Leakage

Limited information is available to the builder on the relative airtightness of various windows. The Canadian Standards Association is working on developing a performance-oriented set of technical requirements for all windows regardless of the construction or material.

This standard is available only as a draft but currently includes as part of its window information a rating based on maximum air leakage.

A few general guidelines can be given (Figure 5.36). Depending on their operating hardware, casement and awning windows generally have more resistance to air leakage than sliding types including double-hung windows simply because their latching mechanisms provide a greater sealing pressure. Sliding windows (either vertical or horizontal), on the other hand, are limited in sealing pressure so that they can remain easy to open and close. Sliding windows also have a greater length of joint to be weatherstripped.

Basement windows should be of the same quality as the main floor windows.

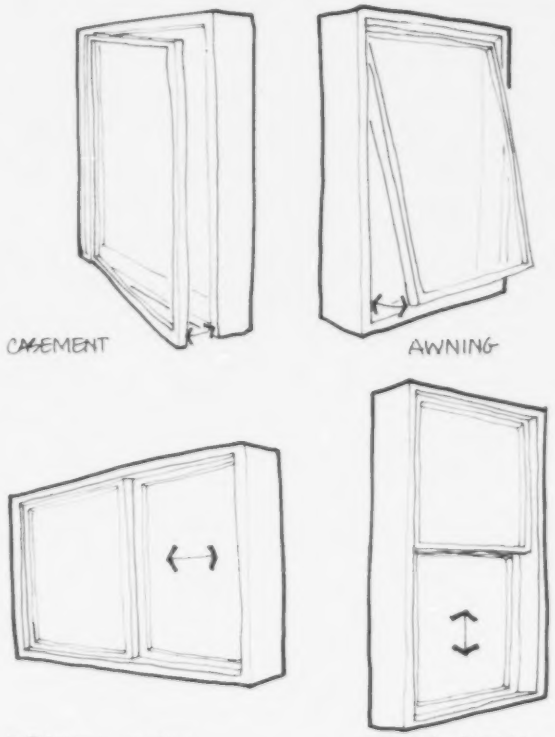


FIGURE 5·36 RELATIVE RESISTANCE TO AIR LEAKAGE

NOTE CASEMENT TYPE AND AWNING TYPE WINDOWS HAVE BETTER RESISTANCE TO AIR LEAKAGE THAN SLIDING TYPE WINDOWS

5.8.5. Installation

Two objectives should be kept in mind when installing windows:

- Be sure to mount the window in square and in plane.
- Be sure the space between the window unit and the frame is well sealed and insulated.

These objectives can best be obtained by ensuring that the frame opening is larger (say 18 mm larger) than the actual dimensions of the window to be installed. The window is easier to install and there is plenty of space left to ensure the even distribution of insulation.

It is highly recommended that urethane foam be used to insulate between the window and the frame opening. This type of foam readily expands to all corners of the opening acting as a sealer as well as an excellent insulator. In contrast, glass fiber insulation does not offer the same sealing feature and it can often be compacted too tight into such a tight space, reducing the insulating effect.

The critical part of window installation involves the sealing of the frame to the air barrier. Three of the most traditional approaches are discussed below.

Polyethylene Wrap

As shown in Figure 5.37 a strip of polyethylene is wrapped and caulked around the outside frame of the window. With the poly skirt facing to the inside of the house, install the window. The skirt can then be folded down and sealed to the air barrier.

Plywood Wrap

In this approach, the rough opening for the window is cut to fit a plywood liner. The wall air /vapour barrier is cut so that it overlaps the edges of the rough opening. The barrier is then caulked to the rough stud. Caulking is then applied over the folded poly and the plywood liner is installed. The window can then be installed flush to the inside or outside of the opening. Any gaps around the window can then be insulated preferably with urethane foam (Figure 5.38).

Drywall Method

This approach should be applied when a structural air barrier is being used. Here the window should be installed in the rough cut frame so that when the drywall is installed it will butt the window frame. The drywall is then sealed to the window frame. The drywall is then taped and the inside trim of the window is installed.

If the window is installed flush to the outside wall, the drywall will have to be carried into the inside frame to butt against the facing edge of the window frame (Figure 5.39).

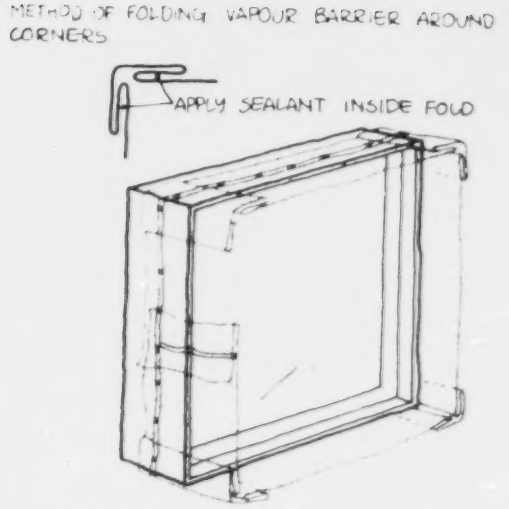


FIGURE 5-37 WINDOW INSTALLATION PROCEDURES

IF STRAPPED OR DOUBLE STUD WALL IS USED, THE WALL POLYETHYLENE AIR/VAPOUR BARRIER CAN BE TRIMMED TO THE EDGE OF THE FRAME CAULKED AND THEN SEALED BEHIND THE STRAPPING USED AROUND THE WINDOW, THUS ELIMINATING THE NEED TO WRAP THE FRAME AS SHOWN ABOVE. SEAL EXTENDED WINDOW TRIM TO WINDOW FRAME AND TO DRYWALL.

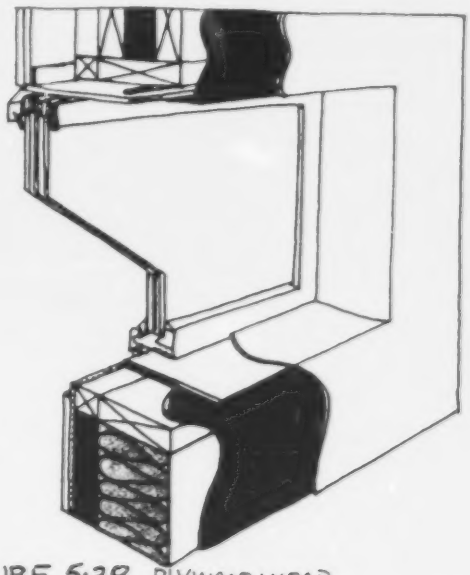


FIGURE 5-38 PLYWOOD WRAP

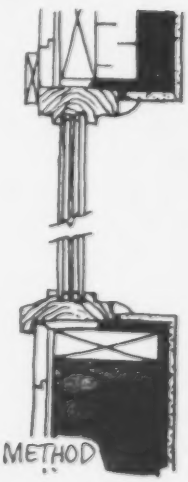


FIGURE 5-39 DRYWALL METHOD

5.9 Doors

While house doors represent a small area of the building envelope, improvements in their thermal performance can result in reduced drafts and improved comfort at the same time as energy savings are realized.

5.9.1 Recommendations

- Use insulated doors unless market considerations dictate otherwise.
- Choose weatherstripping that tolerates some movement of the door and can be easily adjusted.
- Advise home purchasers of the need to adjust weatherstripping.
- Install doors in a manner that avoids distortion and creates an insulated, airtight door/wall joint.

5.9.2 Increased Thermal Resistance

The Ontario Building Code (1983) and CMHC Builders' Bulletin No. 267 require that exterior doors have a thermal resistance of RSI 0.7m^2°C/w or that storm doors be provided. In order of increasing thermal resistance, the various options are:

- a solid core wood door plus a storm door (RSI 0.95);
- an insulated metal or wood door (RSI 1.0 to more than 2.0);
- an insulated metal or wood door plus a storm door (RSI 1.6 to more than RSI 2.6).

As the installed cost of solid core wood doors and insulated doors is likely to be about the same, only such market factors as preference for wood would favour the first option above.

Storm doors are generally not cost effective in terms of energy savings as compared to a weatherstripped insulated door. Market factors such as the desire for a screen door in the summer will be the ruling consideration.

Some caution is required when combining a storm door with an insulated door, especially if the insulated door incorporates decorative plastic moldings as is common practice. With the glass light of the storm door closed and the door exposed to direct sunlight the temperature between the doors can build up beyond the melting point of the plastic. This combination is not advisable on southerly or westerly faces of buildings unless the door is shaded from direct sunlight by trees or overhangs.

5.9.3 Resistance to Air Leakage

Resistance to air leakage around the door is provided by weatherstripping. Unlike windows, doors are not always fitted with weatherstripping by the manufacturer — this is often an on-site installation. Door weatherstripping must also withstand much more demanding conditions than window weatherstripping since:

a) doors are opened and closed more often, and

b) are subject to greater changes in shape as the seasons change.

The most important thing to keep in mind in choosing weatherstripping is that doors do change shape. Wood doors tend to bow outward in winter due to the difference in the relative humidities of the inside and outside air. Metal doors tend to bow at a lesser rate inward due to the difference in temperature between their inside and outside surfaces.

Weatherstripping should adjust automatically to these movements or should be easily adjusted manually. Table 5.3 shows a number of types of weatherstripping and gives their advantages and disadvantages.

Since doors do change shape, and since it is difficult for weatherstripping to be completely self-adjusting, it follows that the home occupant must take an active role in adjusting the weatherstripping if air leakage between the door and the frame is to be kept to a minimum. It also follows that the builder should make the home occupant aware of this need and provide suitable instructions. This information could be included in homeowners' manual.

5.9.4 Installation

The procedures recommended in Subsection 5.8.5 for the installation of windows apply equally well to the installation of doors (Figure 5.40). The need to avoid distortion is even more important with doors because even a small angular distortion can result in large gaps over the two metre height of the door.

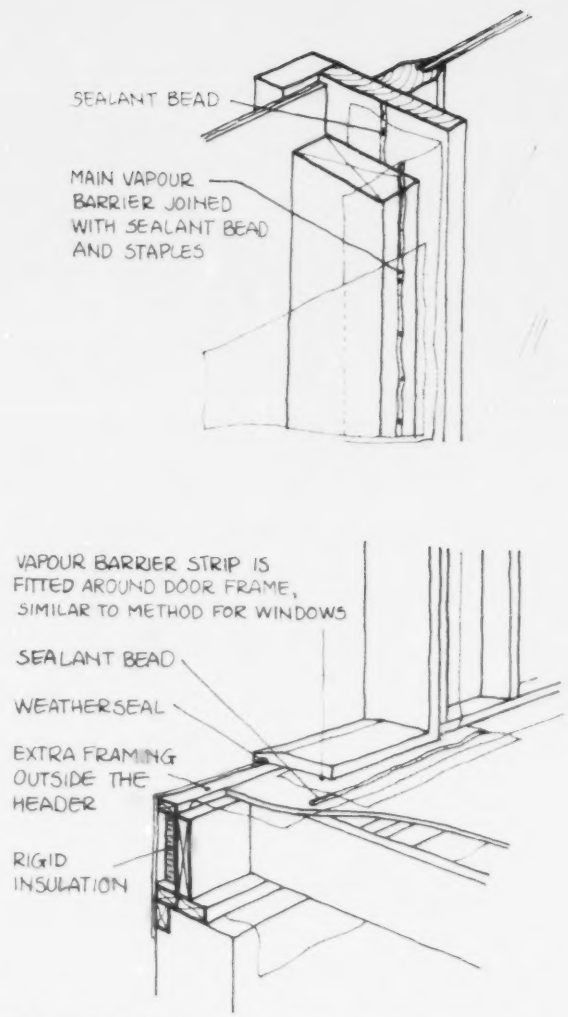
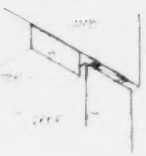
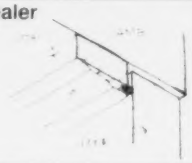
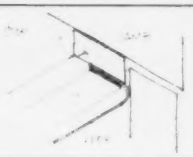
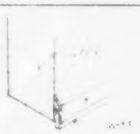
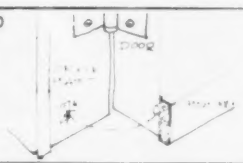
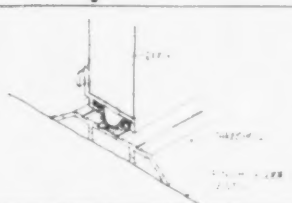
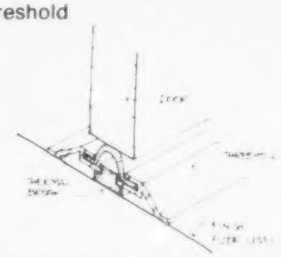

SEALANT BEAD
MAIN VAPOUR BARRIER JOINED WITH SEALANT BEAD AND STAPLES
VAPOUR BARRIER STRIP IS FITTED AROUND DOOR FRAME, SIMILAR TO METHOD FOR WINDOWS
SEALANT BEAD
WEATHERSEAL
EXTRA FRAMING OUTSIDE THE HEADER
RIGID INSULATION

FIGURE 5.40 TYPICAL JAMB SECTION ILLUSTRATING MANY FEATURES OF GOOD WINDOW/DOOR INSTALLATION PRACTICE

Table 5.3 Selection of Weatherstripping

Type	Installation, and Materials	Advantages, Disadvantages
Around doors		
Metal tension 	Nails between door and jamb. Spring metal strip works on same principle but is slightly more difficult to install than strip shown at left. Both easier to install if sold with predrilled holes. Bronze, aluminum, stainless steel.	Doesn't show when door is closed. Good control of drafts. Long life. But: difficult to readjust. Easily tampered with.
Rigid metal-backed sealer 	Nails or screws into stop. Screws take longer to install but are easier to adjust than nails. Position to make gentle contact or door will be hard to close. Aluminium, plain or anodized, with vinyl insert.	Can be adjusted if holes are slotted. Good durability. Keep out drafts, water, noise, light, dust, humidity. But: stripping is visible alongside door.
Rolled metal-backed sealer 	Nails into stop. Aluminium with wool, hair or cotton felt, vinyl.	Keeps out drafts, noise, light, dust. But: visible alongside door or window. Not as durable as rigid metal-backed sealer. Not easily adjusted once sealer loses contact with door or window.
Magnetic	Flexible magnetic seal similar to those used on refrigerators. Usually supplied already installed in frame with pre-hung door.	Very good seal and is flexible enough to accommodate seasonal movement of steel doors. Quite inconspicuous. Only works with steel doors.
Rolled foam	Adhesive-backed strips of foam simply stick to jamb or stop; vinyl-covered foam strips nail on.	Installs in minutes. Doesn't show. Keeps out drafts, noise, light, dust, and humidity. But: temporary; foam soon flattens, breaks down.
Under doors		
Sweep 	Screws into interior side of in-swinging door. Aluminium, stainless steel with sponge, vinyl.	Adjustable. Effective. But: exposed to view. May drag across rugs.
Automatic sweep 	Useful where threshold is flat or there is no threshold. Good durability. But: sweep may not retract quickly enough to pass over edge of threshold or carpet up against door.	Screws onto outside of in-swinging door. Door opens, sweep retracts. Door closes, striker plate causes sweep to lower. Aluminum, plain or anodized, with vinyl, neoprene, or felt drop.
Door shoe 	Fits over door bottom, screws into face. Shoe with slotted screw holes allows adjusting for seal with some margin for error. Aluminum, vinyl insert.	Effective, durable seal. May be used with wood threshold that's not worn down in middle. Usually sold with drip cap that sheds rain. Vinyl insert replaceable. But: before installation, bottom of door may require trimming or door threshold may have to be replaced.
Threshold		
Vinyl bulb threshold 	Fits under door; door bottom should have about ⅛-inch bevel to seal against vinyl bubble. Available in different heights. Metal cap with built-in angle available to fit over bottom of door, offers smooth surface. Aluminum, plain or anodized, and vinyl.	Works as combined threshold and weather strip; useful where there's no threshold or wood one is worn out. Provides good weather seal. But: with wear, vinyl bubble will flatten out, tear, lose effectiveness. (Replacement bubbles sold.)

Section 6
Space Heating and Cooling Systems

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6.1 Heating Equipment Sizing and Selection

This section discusses selection, sizing and loction of heating equipment.

6.1.1 Recommendations

- Avoid oversizing or guessing at the heating plant capacity.
- Calculate required heating plant capacity in accordance with the methods approved by the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI), the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
- Ensure that the output of the heating equipment being considered is equal to or slightly greater than the calculated heating plant capacity.
- Assess the availability and cost of fuels in the particular location being considered prior to selection of heating equipment.
- Locate heating equipment centrally to loads being served as much as possible within building constraints.
- Review other sections of the guide to ascertain desired features of the heating equipment.

6.1.2 Heating Equipment Sizing

The heating equipment must be capable of maintaining the house at 22°C during the heating season. In the past, heating equipment installed in houses has been oversized, leading to frequent on-off operation of the equipment. This reduces both its efficiency and its service life. The unit should be sized to be no more than approximately 20 per cent over the design load of the house.

6.1.3 Heating Equipment Selection

The choice of fuel will be largely based on the availability and relative cost of oil, gas and electricity. When comparing these fuels it is important to obtain the cost per unit of energy delivered to the house, ie: $/GJ (Gigajoules). Appendix F provides conversion factors to assist in this calculation. See Table 6.1 for example.

In order to determine the cost of energy delivered to the house, the average annual or seasonal efficiency of the heating equipment must be used.

GAS	
- Conventional Gas	60-70%
- Non-condensing, medium efficiency	80-90%
- Condensing	90-98%
OIL	
- Conventional	55%
- With flue damper	70%
- High Efficiency (Condensing)	90%
ELECTRIC	100%

Dividing the purchase price of the fuels by the appropriate seasonal efficiency will provide the delivered cost of the heat to the house per unit of energy, $/GJ. See Table 6.1 for example.

Table 6.1 Delivered Cost of Heat

	Purchase Price of Fuel	$/GJ	Heating Equipment Seasonal Efficiency	Delivered Cost of Heat to House
Gas	$ .24/m3	$ 10.81	0.60	$ 6.99
	$ .24/m3	$ 10.81	0.90	$ 7.77
Oil	$ .35/L	$ 15.25	0.60	$ 9.21
Elec	$ .05/kWh	$ 13.88	1.00	$ 13.88

6.2 Combustion Furnaces

This section examines the options available for improving the efficiency of combustion furnaces. The alternatives for oil and gas furnaces are discussed in terms of capital and operating costs.

6.2.1 Recommendations

Gas Furnaces

- Provide the furnace with the highest seasonal efficiency possible, but as a minimum, an induced draft furnace should be installed.

Oil Furnaces

- Choose units with a factory installed flue damper.
- Specify units equipped with oil line solenoid valve and flame retention head as a single package.

6.2.2 Gas Furnaces and Boilers

Most modern gas furnaces and boilers eliminate the need for a pilot light through the use of an intermittent ignition device, or electronic spark ignition. When the house thermostat calls for heat, the pilot jet is turned on and ignited by an electic spark. Table 6.2 shows the annual energy savings available from such devices.

An induced furnace pulls the combustion products through the combustion chamber purging the system before ignition to help maintain proper combustion air availability.

Condensing gas furnaces capture much of the heat which in conventional furnaces escapes up the flue. In conventional furnaces exhaust gas temperature can reach up to 260°C whereas with a condensing furnace, exhaust air is cooled to 36° to 60°C. A PVC pipe can be used to vent these gases outside, eliminating the need for a chimney.

Medium to high efficiency induced draft furnaces draw little air from the house (open system) but have a safety shut off, making them much less susceptible to backdrafting. In general, the more efficient a furnace is the less air it requires from the house. Some systems such as the pulse furnace have their own air supply duct to provide a sealed combustion system entirely separate from the house.

6.2.3 Oil Furnaces

Oil burners and boilers begin their cycle of operation with the activation of the oil pump, combustion air fan and spark ignition. The spray of oil droplets is ignited by the electrodes.

During the first few moments of operation, anywhere from 10 to 30 seconds, combustion is usually incomplete because of low pressure in the fuel line and inadequate draft from the burner fan. This is the main cause of soot buildup in oil furnaces. Incomplete combustion also occurs, to a lesser degree, at the end of the firing cycle due to the failure of the fuel pump to shut off sharply, causing "burner run-on".

Table 6.2

Options for Increased Energy Efficiency in Gas Furnaces as Compared with Conventional Gas Furnaces

Feature	Availability	Annual Energy Savings %
Spark Ignition	factory installed	5-6%
Induced Draft	factory installed	20-25%
Condensing	factory installed	30-40%
Pulse	factory installed	30-40%

Both these problems can be overcome by the use of a delayed-action solenoid valve between the fuel pump and the nozzle. When the furnace starts up, the solenoid valve remains closed to keep the fuel oil from the nozzle until the pump has reached the required pressure and the burner fan has had time to start the air flow through the combustion chamber. At the end of the firing cycle the solenoid valve cuts the fuel off sharply, preventing "burner run-on". Savings come through reduced oil wastage during start-up and shut-down, and through improved operating efficiency. Further savings are possible from the reduced cleaning frequency.

Flame retention heads fit on the end of the oil burner to produce a flame pattern that operates at higher efficiencies. Most new oil burners are equipped with flame retention heads as standard equipment.

Flue dampers are available for oil and gas furnaces. They trap the residual heat inside the furnace, and reduce the loss of inside air up the chimney. Efficiency options and their impact on energy savings are summarized in Table 6.3.

New condensing oil furnaces have been developed with efficiencies similar to those using natural gas. They are relatively new and unproven.

6.3 Air Supply for Heating Equipment

Fuel fired appliances expell air from the house. Any combustion process requires oxygen drawn from the air. Most combustion appliances also require additional air for draft control to ensure that the chimney's draft action is maintained. The draft control air requirement can be much greater than the actual combustion air requirement.

Table 6.4 categorizes various common types of heating equipment into three categories, showing their typical indoor air consumption:

- not requiring an indoor air supply
- requiring combustion air only from inside the house
- requiring combustion and draft control air from inside the house

On units which do not require indoor air, provision of air to the heating equipment is obviously not an issue. On the others, provision of this air must be a consideration.

For all gas-fired appliances this has been formalized in the current natural gas installation code, CAN/CGA D149.1M86. This code provides two separate Tables for the size of a makeup air duct depending on whether the unit requires additional draft control air or combustion air alone. This information has been included here in Table 6.5. The code further specifies that this duct must "terminate within 1 ft (300 mm) above and within 2 ft (600 mm) horizontally from the burner level of the appliance having the largest input". (When two gas-fired appliances are installed ie: furnace and a hot water heater, only one duct is needed going to the largest appliance).

Codes for oil-burning equipment are much less specific. They do have general guidelines for air supply openings outlined in Appendix A of the Installation Code for Oil-Burning Equipment, CSA Standard B139-1976. This suggests an opening should have a free area of not less than

Table 6.3
Options for Increased Energy Efficiency in Oil Furnaces

Option	Availability	Annual Energy Savings* GJ
Solenoid Valve	Factory Installed	1-2
Flame Retention Head	Factory Installed	6-13
Flue Damper	Factory Installed	4-8

*Energy savings will depend on furnace size, building type and location. Savings are not necessarily additive if more than one option is chosen. (Low figure indicates energy savings for a split level house in a 4000 DD (°C) zone, high figure indicates energy savings for a split level house in a 6000 DD (°C) zone)

Table 6.4
Classification of Heating Systems and Air Requirements

Type of Equipment	Energy Source for Heating Air/Water	Typical Indoor Air Consumption (L/s)	Air Supply Source
1. Not Requiring Indoor Air Supply			
• Electric Resistance Baseboard or Plenum	Electric	None	-
• Heat Pump	Electric	None	-
• Condensing Gas Heat Pump	Gas	None	Unit currently available located outside the house
• Sealed Combustion Unit	Gas/Oil	None	Brings in all its air requirements from outside
• External Combustion Unit	Gas/Oil	None	Located outside the house
2. Requiring Combustion Air Only From Inside The House			
• Furnace with Induced Draft	Gas/Oil	12	Motorized damper linked to furnace
• Condensing Furnace	Gas/Oil	8	Motorized damper linked to furnace recommended
• High Efficiency Oil Furnace	Oil	10	Room the furnace is located in
• Stove (used as an airtight unit)	Wood/Coal	5	Room the stove is located in
3. Requiring Combustion and Draft Control Air From Inside The House.			
• Conventional Furnace	Oil	70	Room the furnace is located in
• Conventional Furnace	Gas	55	Room the furnace is located in
• Conventional Furnace fitted with Flame Retention Head	Oil	65	Room the furnace is located in
• Stove with Open Doors	Wood/Coal	55	Room the stove is located in
• Fireplace	Wood/Coal	190	Room the fireplace is located in

1in²/5000 BTU/hr. It should be noted that this code is currently being reviewed and combustion air supply requirements may be revised and made more specific.

Many builders have an aversion to leaving an open duct because of problems with cold air entering through the duct at times when the furnace is off. This creates comfort problems and can add unnecessary air changes, thereby increasing energy costs. There are a number of methods and products available which will minimize these problems. Putting in a heat trap as shown in Figure 6.1 can help to reduce uncontrolled entry of cold air but will not eliminate it. Alternatively, a damper can be used which closes the duct when the air supply is not required. These fall into three basic categories:

- Motorized dampers which are interconnected with the appliance so that the duct is only open when the appliance is on. The appliance will not come on unless the damper is are opened.

- Heat controlled dampers. These dampers have a temperature sensitive activation unit which open the damper when they detect that heat is coming from the furnace. In essence they perform the same function as a motorized damper but with a less positive action. They also have the disadvantage that they serve a single combustion appliance.

- Barometric dampers which sense any pressure difference between inside and outside and open if the house goes into a negative pressure situation. This damper would handle all makeup air requirements including that of the combustion appliances.

6.4 Electric Resistance Systems

This section examines two alternative systems for electric resistance heating. Recommendations focus on proper installation practices to achieve maximum energy conservation. The conversion of electricity into heat is assumed to be 100 percent efficient for both the electric baseboard and the electric furnace case.

6.4.1 Recommendations

Electric Baseboard

- Where electric baseboard heaters are used, supply each room with a wall-mounted low voltage thermostat, or a CSA performance certified line voltage, wall-mounted thermostat.

- Built-in thermostats may be used in baseboard heaters serving the kitchen, bathroom, service or storage rooms, and vestibules.

Electric Furnaces

- When a forced air electric furnace is used, it should permit staging of the heating elements via the use of external thermostats.

6.4.2 Electric Baseboards

Baseboard heaters use resistance wires or rods to produce heat and are usually located in each room of the house. They can provide individual room temperature control. This system has a flexibility that central systems do not in that rooms can be kept at different temperatures or can be closed off and left at lower temperatures.

Table 6.5 Combustion Air Requirements

Combustion Air Requirements for Appliances NOT Having a Draft Hood or a Drafr regulator, where the Combined Input is 120 kWh (400,000 Btuh) or Less

(Structure Complies with Clause 6.2.1)

Total Input of Appliances kWh (Thousands of Btuh)	Acceptable Approximate Round Duct Equivalent Diameter in mm (in.)
15 (25)	50 (2)
23 (50)	75 (3)
30 (100)	75 (3)
37 (125)	100 (4)
45 (150)	100 (4)

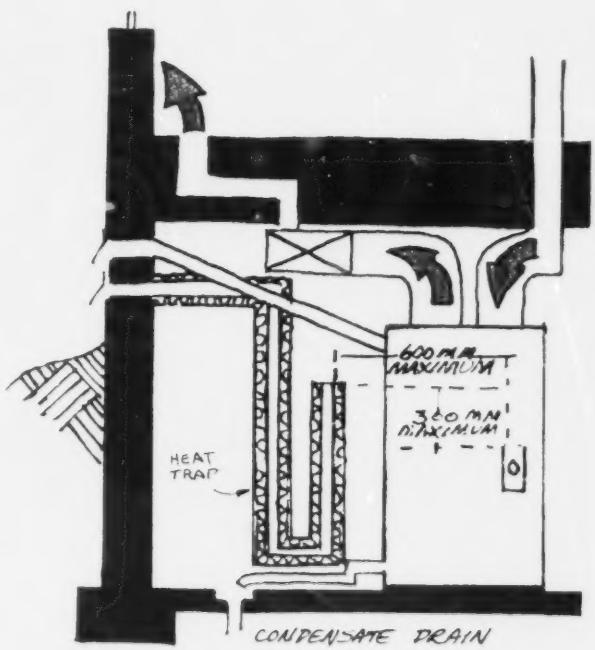


FIGURE 6·1 PROVIDING EXTERIOR COMBUSTION AIR

6.4.3 Electric Furnaces

Forced air electric furnaces are centrally located and operate like a conventional combustion furnace, using a similar blower and ductwork for distributing the heat throughout the house. The thermostat turns on the heating coils in stages when there is a demand for heat. The output capacity is determined by the number of heating coils, or the kilowatt rating of the furnace. Forced air electric furnaces have the advantage of allowing for the addition of such features as air filters, air conditioners, and heat pumps. They also provide air circulation which reduces the buildup of humidity and odours in local areas.

6.5 Heat Pumps and Central Air Conditioning

This section examines heat pumps and central air conditioning systems.

6.5.1 Recommendations

Heat Pumps

- If a heat pump is to be used in locations with 5000 DD (°C) or less, it should have a coefficient of performance (COP) greater than 1 at -12°C.
- If a heat pump is to be used in locations with more than 5000 DD (°C) provide a machine with a COP greater than 1 at -23°C.
- If an add-on heat pump system is to be used, it should consist of an efficient furnace as outlined in Subsections 6.2.2 and 6.2.3 and a heat pump with performances as outlined above.
- Employ the services of a contractor skilled in the installation of heat pumps.
- Ensure the availability of a qualified heat pump service contractor in the area.

Central Air Conditioning - Refer to Subsection 6.8 for an alternative to central air conditioning systems.

If a central air conditioning system is required:

- Provide a central air conditioning system with a minimum energy efficiency ratio (EER) of 10kJ per watt.
- Retain the services of a contractor skilled in the installation of central air conditioning systems.
- Ensure that the air conditioning system installed is the minimum required to achieve desired space conditions. Size equipment in accordance with HRAI or ASHRAE standards.
- Consider the use of a heat pump system in lieu of an air-conditioning system only.

6.5.2 Air to Air Heat Pumps

An air to air heat pump is another form of electric heating. It uses electrical energy to withdraw heat from the outside air, raises its temperature and discharges its heat to the space being heated. Mechanically it is simply a refrigerator working in reverse (Figure 6.2). In the summertime the cycle may be reversed to cool the building and transfer the heat to outdoors, operating as an air conditioner.

The efficiency of this heat transfer is referred to as the coefficient of performance (COP) of the machine. Simply stated the COP is the net useful heating effect divided by the energy used both to provide summertime cooling and wintertime heating.

Air to air heat pumps are available in two basic designs, single-speed compressor and two-speed compressor.

A single-speed heat pump operates on demand from the house thermostat to supply the necessary heat. If the compressor is unable to meet the load, electrical resistance heating elements switch on to provide the additional heat required.

One recent improvement is a heat pump with a two-speed compressor. Such a machine offers higher COPs at below-freezing outdoor air temperatures than the single-speed machine.

Operation of a two-speed heat pump is identical to the single-speed machine, except that the compressor runs faster at sub-freezing temperatures.

The COP of a single-speed heat pump is usually greater than 1 at -12°C. These machines are more cost effective in areas with 5000 DD°C or less. Two-speed heat pumps have a COP greater than 1 at -23°C. These machines provide a more cost effective alternative in locations with more than 5000 DD°C.

The add-on heat pump is identical to the single- and two-speed heat pumps except that the auxiliary energy required to meet the heating load is supplied by a combustion furnace, and the heat pump unit does not function below approximately 0 degrees C (Figure 6.3). The major benefit of this system arises from the fact that combustion heating is currently less expensive than electrical resistance heating (see Subsection 6.1.3).

Add-on heat pumps should consist of the appropriate selection of a heat pump machine described above, and an efficient furnace as described in Subsection 6.2. In this manner an efficient heating package will be ensured.

Even the best heat pump system is of little value if it is not properly installed. Ontario Hydro found that a significant percentage of heat pumps were not properly installed in the first place, and further, that the servicing of these machines had actually reduced the performance because of improper modifications of the control setpoints. It is important that only contractors who are skilled in the installation of heat pumps be used. Installation must be in accordance with CSA Standard C273.5M. The availability of qualified servicemen must also be assured.

Installation "Form A" available from Ontario Hydro should be completed by the installer. This will provide some assurance that the heat pump is properly installed.

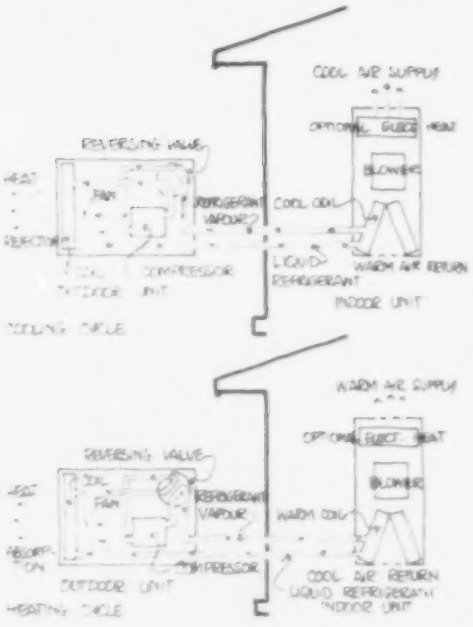


FIGURE 6.2
BASIC HEAT PUMP OPERATION

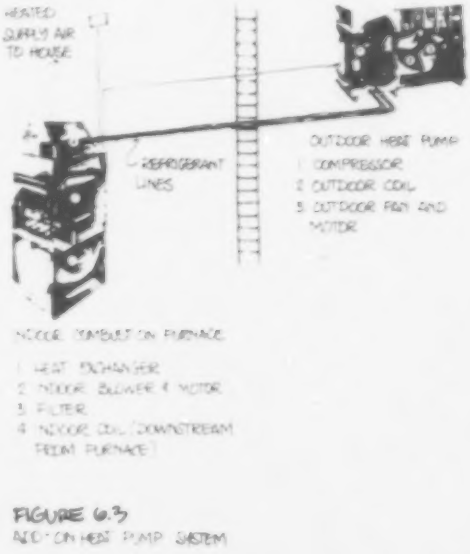


FIGURE 6.3
ADD-ON HEAT PUMP SYSTEM

On a pure energy saving/capital cost basis, air-to-air heat pumps are generally not cost effective in homes which are designed to be highly energy efficient, such as the R-2000 homes. The low overall demand for space heating in these houses cannot justify the increased capital cost of a heat pump. (Figure 6.4). If air conditioning is a requirement, the incremental cost of a heat pump may be justified because of energy savings. Maintenance costs must also be factored into the equation.

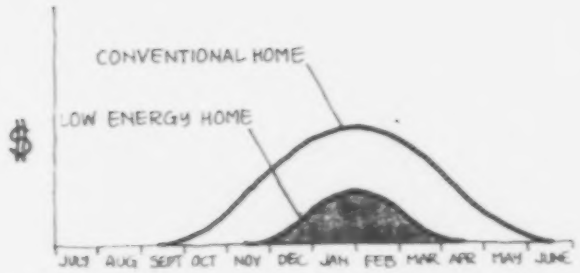


FIGURE 6-4 RELATIVE SPACE HEATING DOLLAR REQUIREMENTS

Ground or water-source heat pumps are gaining increasing market acceptance. While their installed cost is usually more expensive these units can save a higher percentage of the heating requirement as the heat source is warmer.

6.5.3 Central Air Conditioning System

An air conditioning system cools the air that is circulated through the house. The heat that is removed from the house is transferred outdoors by a condensing unit located outside the house.

Central air conditioning systems require electrical energy to operate the compressor, but some are more efficient than others. Manufacturers rate their products in terms of an energy efficiency ratio, EER. This is simply the amount of heat removed from the space (in kJ) divided by the power required in watts. An efficient machine will have an EER of 10 or greater.

Efforts should be made to reduce air-conditioning requirements. Some methods are discussed in sections 6.8.

If air conditioning is to be provided, consider installation of an air-to-air heat pump to provide both heating and cooling.

6.6 Heat Delivery and Control Systems

This section examines the requirements of heat distribution and control systems that will reduce problems of uneven heating throughout the house.

6.6.1 Recommendations

Forced Air Systems

Install ductwork, diffusers and grilles in accordance with standards established by HRAI and ASHRAE. In particular:

- Provide balancing dampers in ductwork at all takeoffs.
- Provide adjustable diffusers.
- Channel return air from house to heating equipment using a minimum of one collection point per floor.
- Where enclosed joist spaces are used for return air, they must be tightly sealed and of adequate free area.
- Wherever possible, lay out ductwork so that straight unobstructed runs are obtained.
- Insulation of ductwork to RSI 0.5 will assist even distribution of heat within the house.

- Air systems should be balanced in accordance with practices established by HRAI or ASHRAE. The occupant of the house should be instructed how to change the warm air distribution within the house to suit personal desires.

- Tape all joints in ductwork.

- Ducts should be arranged so that they do not pass through unheated spaces or exterior walls.

- If central air conditioning is to be added to the distribution system, the blower must be capable of providing the additional static pressure required.

Hot Water Systems

- Provide a self-balancing water heating system either using two pipes with balancing valves, or a single pipe system with automatic control valves.

- Provide balancing and shut-off valves on all radiators.

- Install foil-faced insulation board between radiators and external walls to reduce heat losses to exterior of building.

- Insulate all supply water piping to RSI 1.0.

Heating System Controls

Locate thermostat(s) as follows:

- Mount on an inside partition wall about 1.5 metres from the floor, and keep away from windows and doors that open to the outside.

- Avoid mounting on an outside wall or on either side of a wall exposed to direct sunshine; near wall areas warmed by the kitchen range or refrigerator on the other side; or on walls containing pipes or air ducts.

- Locate away from radiators, warm air registers, and any heat-releasing appliances (T.V., lamps, etc.)

6.6.2 Forced Air Systems

Forced air systems distribute air, warmed by the heating equipment, to the residence by a supply and return duct system. To provide even heating a proper distribution system is required. Construction of such a distribution system may be accomplished through adherence to sizing and installation practices established by the HRAI and ASHRAE. The most important requirements are listed in Subsection 6.5.1.

The best duct system is of little benefit if the air supply is not properly balanced. Also, the occupant of the house should be told how to modify the temperature of various rooms to suit personal requirements through adjustment of the air flows.

To reduce unwanted heat losses, ducts should be arranged so that they do not pass through unheated spaces or exterior walls. If this is not possible due to building constraints, the ducts should be taped at the joints and insulated to the RSI value of the wall. (Figure 6.5.)

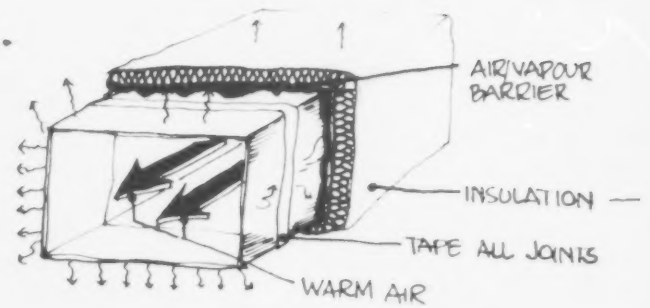


FIGURE 6.5 INSULATION OF HEATING DUCTS

6.6.3 Hot Water Systems

Hot water heating systems are generally used in multi-unit residential buildings, where one heating plant supplies the heat for the entire building. Compact systems are sometimes used for single-family homes.

The water is heated to 50 - 100 degrees C in the boiler and pumped through the system to radiators located in individual rooms before returning to the boiler for reheating. Most boilers have a 5-10 litre capacity that allows quick response to a heating demand and keeps standby losses to a minimum. Boilers may be fired by gas, oil or electricity.

To provide an even distribution of heat to the various rooms in the house, a self-balancing system such as shown in Figure 6.6 or 6.7 should be used. The two-pipe system will supply hot water of uniform temperature to each radiator. Balancing valves on the radiators permit individual adjustment of heat supply. The one-pipe system with automatic control valves will vary the flow of water through the radiators to meet the room load.

A variation of the above is the loop or zone system with each zone being thermostatically controlled.

Radiators supply heat to the room through a combination of convection and radiation. A foil-faced insulating board placed between the radiator and external wall will reduce heat losses to the exterior of the building.

Like the ducts in a forced air distribution system, the plumbing in a hot water heating system should be arranged so that the pipes will not pass through unheated spaces or through exterior walls. All water supply piping should be insulated to RSI 1.0 to reduce unwanted heat losses and assure a more even distribution.

When using hot water heating in an energy efficient house, a separzate ventilation system will be required to provide fresh air and room air distribution.

6.6.4 Heating System Controls

The number and types of thermostats used to control a heating system will depend largely on the nature of the heating system itself. Central heating plants such as forced-air systems are controlled with a single thermostat which should be mounted in a location where it will measure an average house temperature and not be affected by artificial or transient effects. This usually means an interior wall location away from hot air registers and sunshine through windows.

Baseboard heated houses, whether they be hydronic or electric, can have individual room control with a thermostat in each room. The best thermostats for this purpose are the ones which operate a relay which controls the heating unit or valve. Line voltage thermostats are also available but tend to be much less sensitive allowing fairly broad, sometimes uncomfortable, temperature swings.

One thing that has become much more common in recent years is the use of night set back or programmable thermostats which automatically turn down the temperature at times when temperature requirements are reduced. While there is certainly savings to be gained by using a night set back (Table 6.6 shows estimates of savings that can be obtained with night set back), the value of the savings has to be weighed against comfort issues and capital cost of the thermostats.

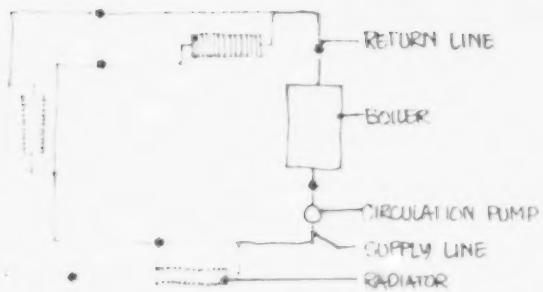


FIGURE 6.6 TWO-PIPE HOT WATER SYSTEM

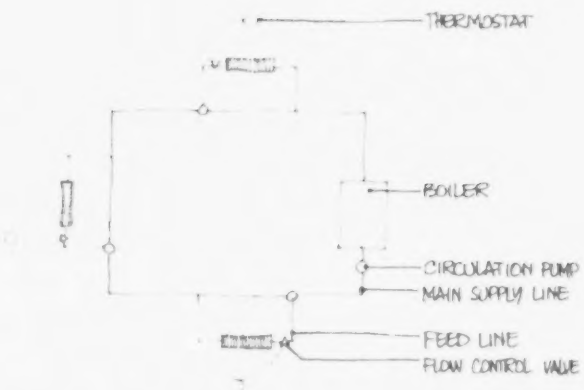


FIGURE 6.7 ONE-PIPE HOT WATER SYSTEM WITH INDIVIDUAL RADIATOR CONTROL

Table 6.6
Annual Energy Savings from Night Time Thermostat Setback Assuming Daytime Setting of 22°C

Temperature Setting	Annual Energy Savings* GJ
22°C	Base Case
20°	4-8
18°	6-12
16°	8-16

* Energy savings will depend on furnace size, building type and location. (Low figures indicate energy savings for a split level house in a 4000 DD (°C) zone, high figures indicate energy savings for a split level house in a 6000 DD (°C) zone, using gas. With a setback period of 8 hours.)
** Accounting for automatic setback thermostat.

Any building has a certain thermal lag. When a furnace is shut off it will tend to cool slowly. Depending on the size of the heating plant, a certain amount of time is required to heat the building to the temperature of the thermostat setting. In heavily insulated buildings, the cooling rate can be quite slow, meaning that the actual benefits of lowering the thermostat is reduced. Also, if the sizing of the heating plant is very close to the actual heating load of the building, the response time on an increase in the thermostat setting can also be fairly long. These factors tend to reduce the period in which real energy savings are obtained. In very energy-efficient houses, with well-sized heating systems, the actual value of the savings gained by night set back may not warrant the cost of the more complex thermostats.

6.7 Supplemental Heating Systems

This section examines heating systems which are not generally used as the sole source of heat in a residence including fireplaces, wood stoves, and enhanced passive solar systems.

6.7.1 Recommendations

Fireplaces

- Where fireplaces are provided, incorporate tight-fitting glass doors to close off the front of the fireplace.
- Add a combustion air supply directly from outside to the front of the fire box. Look for a certified zero clearance type steel insert fireplace.
- Provide heat-circulating fireplaces with natural or forced convection of room air around the heated perimeter of the fire box.

Woodstoves

- Ensure that the woodstoves are installed in accordance with manufacturers' recommendations and existing codes, such as the Canadian Heating Ventilating and Air Conditioning Code (CHVAC) to prevent fire hazards. See also CMHC "Heating with Wood Safely", NHA#6178, Feb. '79.
- Wood stoves must not be combined with standard combustion furnaces unless they are purchased from a manufacturer as a single unit, and are approved for the intended use by the regulating authorities.
- Provide combustion air supply, ducted from the exterior.
- Install louvres communicating with other parts of the house to promote convection of room air over the stove.

Enhanced Passive Solar Systems

- Refer to Subsections 2.2.4 and 2.2.5 for recommendations on siting, landscaping and window considerations.
- Review Subsection 6.7.4 with regard to enhanced passive solar systems.

6.7.2 Fireplaces

Traditional built-in fireplaces can lead to increased fuel consumption in houses due to their inefficient design. They can also be dangerous. When a fireplace does not have adequate combustion air, it uses fuel inefficiently, creates high levels of smoke and carbon monoxide, can deposit creosote in the flue (a potential fire hazard) and cause water to condense in the flue. A roaring fire can require draft air of more than 190 litres per second. This draft can be so strong that it can lead to backdrafting of other appliances.

Another dangerous situation occurs when a fire is smoldering. A significant volume of dangerous gases is still being produced but the draft up the flue is weak. Other appliances in the house which require air from the house may reverse the draft from the fireplace, pulling the products of combustion into the house.

If a fireplace is a requirement for the house, the best type of fireplace to use is one which draws little or no air from the house for combustion. Fresh air should be drawn directly into the fireplace, preferably into the fire box itself. Doors, such as folding glass doors, must completely close off the fireplace from the house except for setting a fire or cleaning. A certified zero-clearance fireplace has all these features (Figure 6.8). The best ones for a tight house are those approved for mobile homes. Refer to CSA Standard B366.2-M1981, Space Heaters For Use With Solid Fuels (also known as ULC Standard S627-M1981).

To eliminate heat loss through the brick, a fireplace can be located on an inside wall or insulation can be placed around the fireplace with proper clearance for combustible materials.

A built-in circulating fireplace allows for greater heat recovery by drawing in cool room air through vents located near the bottom and circulating it through the double-walled sheet metal firebox where the air picks up heat and returns to the living area via the upper vents (Figure 6.9). Circulation occurs by natural convection, although some units use blowers to increase the air circulation rate.

An interesting alternative to the built-in fireplace is the combination stove-fireplace. In this, the front door of the stove opens to permit direct viewing of the fire (Figure 6.10). When the door is closed, the unit has the seasonal efficiency of a good wood stove.

Always check for certification to a Canadian standard — either CSA, ULC or Warnock Hersey when considering using wood burning equipment. Refer to combustion equipment codes to ensure sufficient air for proper furnace operation.

6.7.3 Woodstoves

In areas where wood is available at little or no cost to the occupant of a house, woodstoves are becoming popular for offsetting the space heating load. It is important that any wood-burning equipment be installed in accordance with manufacturers recommendations and existing codes such as CMHC to prevent fire hazards. A sample requirement is illustrated in Figure 6.11. In all cases, adequate combustion air supply must be considered.

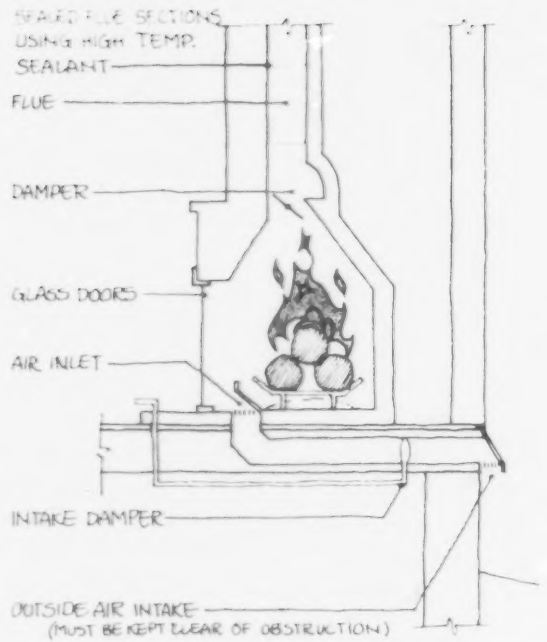


FIGURE 6·8 ZERO CLEARANCE FIREPLACE

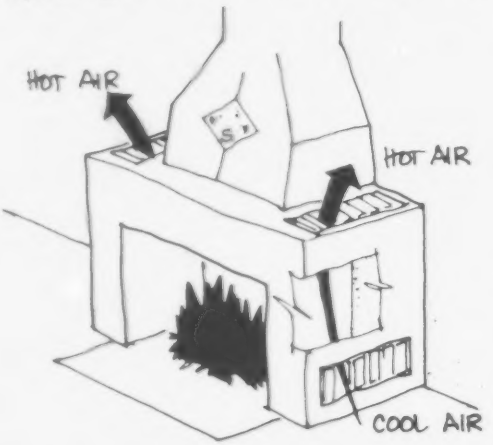


FIGURE 6·9 CIRCULATING FIREPLACE

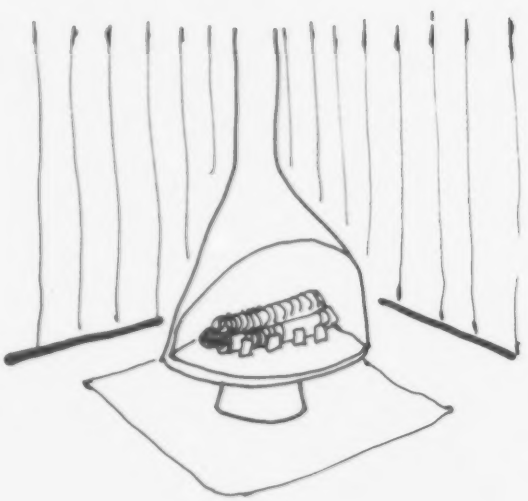


FIGURE 6·10 TYPICAL FREE-STANDING PREFABRICATED METAL FIREPLACE.

CSA now has standards for add-on fuel-fired furnaces and boilers included in the CSA standards for solid fuel-burning equipment. This equipment may create hazards arising from interconnection including the danger of ignition in the event of a gas leak. Overheating of the duct if electrical power to the blower fan is interrupted is another concern. For these reasons the equipment should be installed by experienced tradesmen. More importantly, such interconnection could void CSA or ULC certification of existing furnaces. Combination furnaces designed to use both wood and fossil fuel, wood and electricity, wood and gas, or wood and coal have been approved by either CSA or CGA as well.

When considering such units, make sure that they carry CSA and ULC certification. Remember too, that installation requirements of ductwork and flues attached to woodburning equipment are different from standard furnaces. Careful attention to the appropriate codes is necessary to ensure occupant safety.

Modern airtight wood stoves have seasonal efficiencies up to 65 percent. Since they are airtight, the air supply to the stove can be controlled, thus reducing drafts and extending the wood's burning time. Slow burning increases the rate of creosote build-up in the flue, however. Therefore, ready access to the chimney is required to permit cleaning.

To obtain maximum benefit from a wood stove, registers should be located at the ceiling and floor levels of the room in which the stove is located to promote the circulation of air to adjacent rooms (Figure 6.12). Fans can be used to increase the air flow.

6.7.4 Enhanced Passive Solar Systems

Use of solar radiation to offset the heating load of a building through positioning of the house and windows was examined in Subsections 2.2.4 and 2.2.5. This subsection presents methods that will increase the heat delivered to a house by solar radiation.

Passive solar design relies on southern orientation of the building, with few windows on the east and west sides, and minimal window area to the north. In-coming sunlight will generate heat when it strikes any object. Where the ratio of window area to floor area is large, overheating may occur. In conventional wood frame construction, a good figure to work with is to limit south-facing glazing to 7 percent of floor area (Figure 6.13). This ratio can be increased by providing additional "thermal mass" (heat storage capacity) such as concrete floor slabs, a double layer of drywall, heavy concrete walls, or even phase change materials, which will absorb heat from the sunlight and release the stored heat back into the interior space. Appropriately sized thermal mass will prevent wide temperature swings associated with overheating.

Overheating can also be reduced on south-facing windows by using overhangs. These shade the windows when the sun is high but allow access of the lower winter sun.

In order to make full use of solar gain it is necessary to think about circulating air in the house to distribute heat gained in "sunny" rooms. This can be done through the forced air heating system's circulation system. Otherwise, separate arrangements can be made.

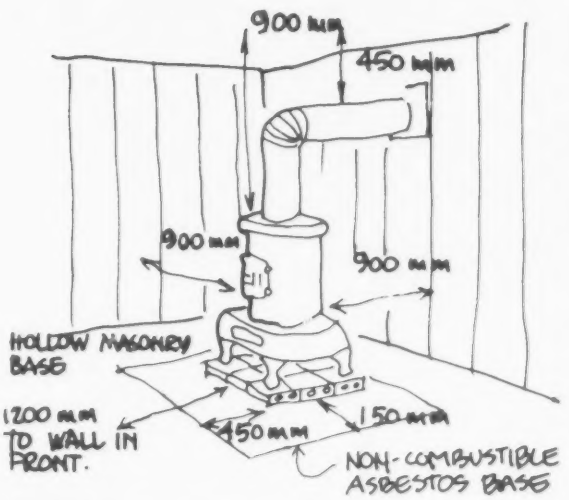


FIGURE 6·11 WOOD STOVE CLEARANCES

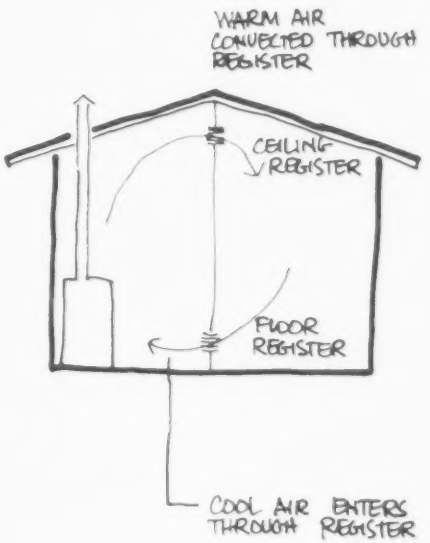


FIGURE 6·12 REGISTERS TO PROMOTE AIR CIRCULATION

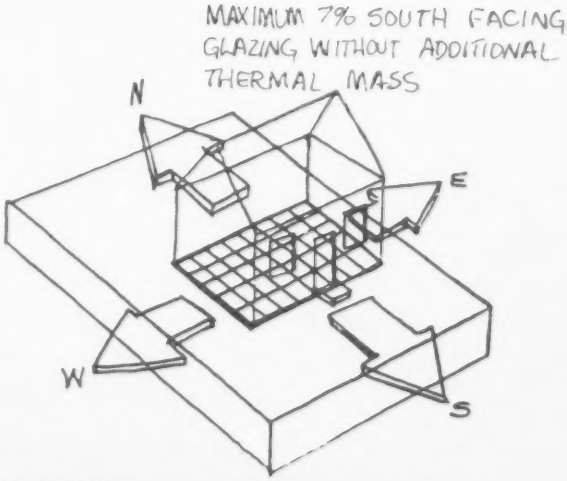


FIGURE 6·13 GLAZING TO FLOOR AREA RATIO

6.8 Summer Cooling Through Ventilation

The use of mechanical refrigeration equipment to provide air conditioning within the house during the summer has become common in recent years. This incurs both a capital and energy cost so that alternative methods of cooling the house during hot weather warrants examination. Tighter construction and improved insulation will do much to reduce the need for mechanical cooling. Reduction of air conditioning loads can also be accomplished by improving natural ventilation in the building or providing a fan to force the ventilation.

6.8.1 Recommendations

- **Consider provision of an attic exhaust fan in lieu of a mechanical air conditioning system for summer cooling needs.**

6.8.2 Cooling Through Natural Air Change

If the air inside the house is warmer than outside, providing a high air change rate will lower the indoor temperature. When it is warmer outside than inside, as it usually is on a hot summer day, it is more desirable to limit ventilation levels to the minimum required for comfort and health.

Effective natural ventilation hinges on effective use of two naturally available driving forces; wind pressure and stack effect.

Wind forces are directional. To maximize the benefit of wind requires planning where operable windows are located in the building to achieve an even distribution of air from one side of the building to the other (Figure 6.14).

Stack effect operates because hot air rises. There should be an opening at the top to let hot air out and openings at the bottom of the building to let cool air in.

6.8.3 Exhaust Fans

Natural forces for ventilation vary and often aren't available when most needed. Providing exhaust fans to force ventilation of the house or the attic is the next obvious step. A high capacity exhaust fan can improve the ventilation in the house and reduce nighttime temperature by bringing in cooler outside air. During the day the house will generally be cooler than outdoors, so the exhaust fan would not be used.

Some of the heat comes from the high temperature in the attic being conducted through the ceiling to the rooms below. Although high ceiling insulation levels will minimize this problem, a fan venting the attic will also help by lowering the air temperature in the attic (Figure 6.15).

A whole house exhaust fan should be capable of exhausting the entire air volume of the house at least once every 30 minutes. The most convenient location for the fan is in the gable ends. The fan should be wired to a convenient wall-mounted switch to permit ready operation of the fan by the occupant.

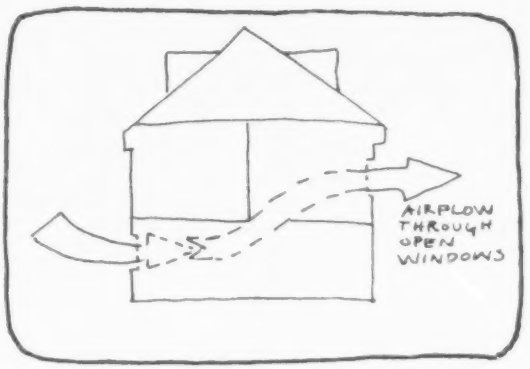
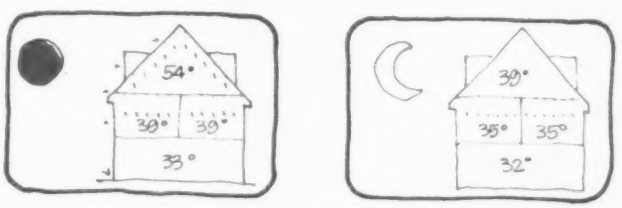
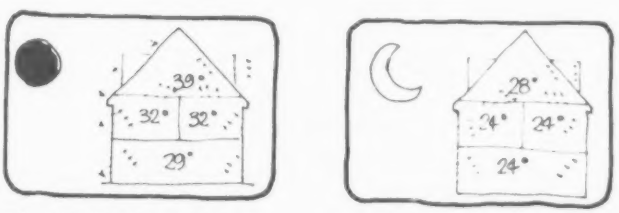


FIGURE 6·14 NATURAL VENTILATION



DAYTIME TEMP DISTRIBUTION NIGHTTIME TEMP DISTRIBUTION

WITHOUT FAN



DAYTIME TEMP DISTRIBUTION NIGHTTIME TEMP DISTRIBUTION

WITH EXHAUST FAN

FIGURE 6·15
SUMMER VENTILATION

Section 7
Domestic Hot Water Heating

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7.1 Domestic Hot Water

This section examines means for conserving hot water, sizing of the storage tank, alternative storage tank designs, and solar heating of domestic hot water.

7.1.1 Recommendations

Consumption and Conservation

- Provide restricted flow fittings on all lavatory faucets and shower heads.
- Provide an insulated heat trap on the discharge piping of the hot water tank.

Sizing Principles

- For a dwelling with 3 bedrooms or less, provide a 0.18 cubic metre storage tank with a minimum heater capacity of 4kW.
- For a dwelling with 4 bedrooms, provide a 0.27 cubic metre storage tank with a minimum heater capacity of 6 kW.
- Locate the domestic hot water tank as close as possible to the fixtures being served.

Electric Hot Water Tanks

- Provide domestic hot water tanks with a minimum of RSI 1.7 (if factory installed) insulation.
- Set thermostat at 50 degrees C.

Gas Hot Water Tank

- Install an induced draft or sealed combustion water heater.

7.1.2 Consumption and Conservation

The average family of four consumes 270 litres of hot water each day. An estimate of consumption by activity is provided in Table 7.1. It can be seen that hot water use in bathroom showers, and kitchen and bathroom sinks acounts for over 35 percent of total hot water consumed.

Flow restricting devices may be installed directly into fittings to reduce the flow rate of faucets and showers. For faucets delivering between 14 and 18 litres of water a minute, flow restrictors could reduce the flow to 5-8 litres per minute while maintaining satisfactory performance.

Another water conservation technique involves installing restrictor aerators in kitchen and bathroom sinks to reduce splashing. This also reduces the flow rate to about 3 litres per minute by introducing air bubbles into the stream of water. Spray taps do not aerate the water, but restrict the flow to 4 or 5 litres per minute by delivering it in a broad pattern of droplets.

Table 7.1
Daily Hot Water Consumption for a Family of Four*

Activity	DHW Consumption Litres
Dishwashing	30
Kitchen Sink	25
Laundry	135
Showers and Bath	53
Bathroom Sink	27
TOTAL	270

* Derived from Energy Efficient Home Operation Program by Canadian Electrical Association.

Special showerheads with adjustable volume control are available for a small additional cost. Table 7.2 shows the relative annual energy savings from each of these devices.

7.1.3 Reducing Pipe Losses

A major source of heat loss occurs in the first 1.5 metres of hot water piping connected to the tank. Natural convection circulates the water from the tank into the discharge pipe where it is cooled by the surrounding air. Insulating this length of pipe will only cause the water to travel farther before it cools. Use of a 'heat trap' will retard convective water losses by preventing natural convection from taking place (Figure 7.1).

7.1.4 Sizing Principles

Domestic hot water tanks are available in two common sizes, 0.18 cubic metres and 0.27 cubic metres. The water is heated by electric resistance elements, oil burners, or gas burners which come in a wide range of sizes. The size of heater needed depends on the occupants' habits — not only the volume used , but also the peak load demand. Recommended tank volumes and heater capacities are provided in Subsection 7.1.1.

7.1.5 Electric Hot Water Tanks

Electric water heaters operate at approximately 83 percent annual efficiency. The transfer of electric energy to the water as heat is 100 percent efficient, but 14 percent of this heat is lost through the insulated tank wall. Standard heaters are insulated with five centimeters of glass fibre to meet the standby heat loss standard established by CSA-191, but new tanks are available with higher levels of factory installed insulation.

Water heaters are equipped with thermostats controlling heater operation to maintain the desired water temperature. It has been common practice to set these thermostats at 60 degrees C. Reduction of the thermostat setting to 50 degrees C will not affect occupant comfort but will reduce standby losses through the insulated jacket.

Table 7.3 summarizes these options.

Table 7.3
Options for Reducing Energy Consumption in Electric Domestic Hot Water Heaters

Option	Availability	Annual Energy Savings GJ
2.54 cm extra glass fibre jacket insulation	Field applied	0.5
Thermostat Setback 60°C to 50°C	Field set	1

Table 7.2
Options for Reduced Domestic Hot Water Consumption

Conservation Device	Annual Energy* Savings GJ
Shower: Flow Restrictor	3-5
Adjustable Volume Control	3-4
Faucets: Flow Restrictor	1-2
Restrictor Aerator	1-2
Spray Tap	1-2

* Annual energy savings will depend on annual consumption. The left hand column assumes electric water heaters and the right hand column assumes gas water heaters.

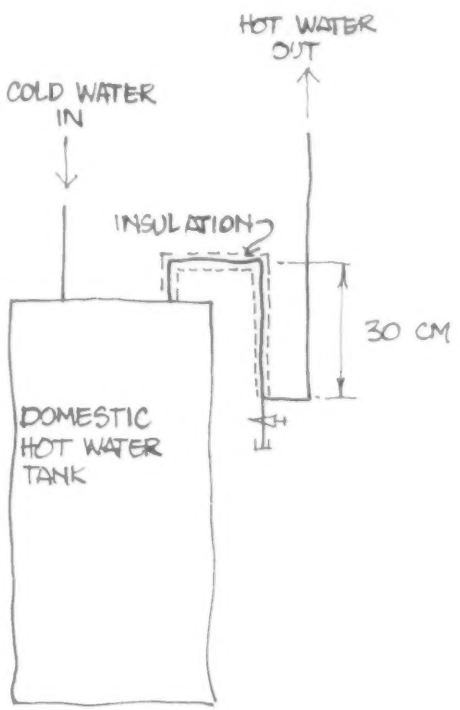

FIGURE 7.1 INSULATED HEAT TRAP

7.1.6 Gas Hot Water Tanks

The annual efficiency of a conventional gas hot water heater is approximately 50 percent. About 12 percent of the fuel energy input is list as heat conducted through the tank walls and insulating jacket; approximately 3 percent is lost in the hot water line during standby, and the remaining 35 percent is lost up the flue, in the form of hot combustion gases. Potential savings are listed in Table 7.4.

Recently there have been developments for improved efficiency gas hot water heaters. One model uses a fan-induced draft system which enables the exhaust to be vented out a side wall. Another has a closed combustion system. These hot water heaters are meant to be used in houses with high efficiency furnaces which do not require chimneys (Figures 7.2 and 7.3). The naturally-aspirating gas hot water heaters are relatively susceptible to backdrafting; particular attention must be placed on the code-required combustion air supply.

As with electric water heaters, set-back of the thermostat to 50 degrees C will reduce undesired heat losses. Highly-insulated tanks are available.

7.1.7 Heat Pump Domestic Hot Water Systems

A relatively new development in the hot water heating field is the use of heat pump domestic hot water systems. There are 2 basic kinds. The first extracts heat from inside the house and upgrades it to the temperatures required for the domestic hot water. While in the heating season the heat taken out of the house may have to be replaced, in the summertime this is not necessary, and the energy required to transfer the heat via the heat pump is typically about one-third of that required to heat the hot water directly. Even in wintertime many houses have waste heat from the furnace in the basement so that not all of the heat transferred to hot water need be replaced.

The second type of system was mentioned in Chapter 4, the heat pump exhaust air heat recovery system. Some of these use the heat pump to extract heat from the outgoing exhaust air of a central ventilation system, and supply it to the hot water system. Since the hot water heating requirement of a house does not vary very much seasonally, this system can be particularly advantageous in well-insulated houses in which the internal or solar gains provide much of the space-heating required.

7.1.8 Instantaneous Water Heaters

One way of totally eliminating standby losses is to have a hot water heating system that only heats the water when it is actually required. There are both electric and gas systems which do this. They are commonly referred to as instantaneous heaters. They can be arranged so that one such heater supplies all the hot water in the house or, for even more energy savings, providing a hot water heater at each point of use. This type of system is worth examining especially where low flows of hot water are required. Obviously, if the water is heated all at once a high rate of hot water use would imply a high power requirement for electric units or high burner and heat exchanger capacity for fuel-fired units. The low-cost, low-power requirement and storage capability of the tank type hot water systems makes them very difficult to beat in the North American market.

Table 7.4
Options for Reducing Energy Consumption in Gas Domestic Hot Water Heaters

Option	Avail-ability	Annual Energy Savings* GJ
Thermostat Setback 60°C to 50°C	Field Set	1
Increased Flue Baffling	Factory Installed	1

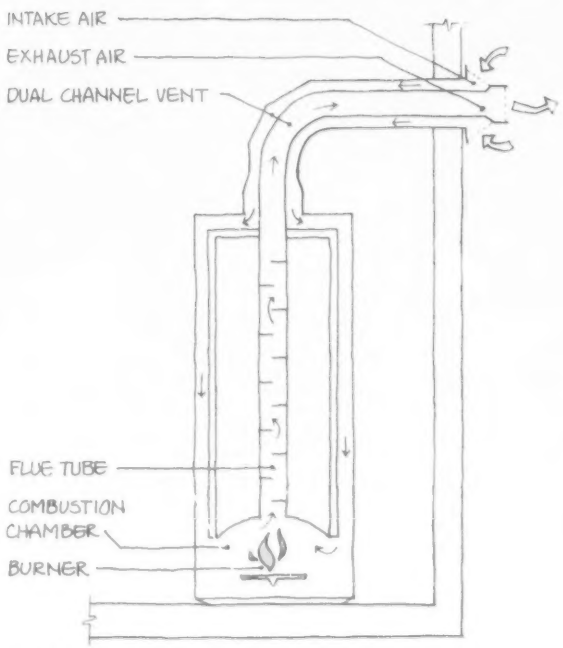

FIGURE 7·2
CLOSED COMBUSTION GAS WATER HEATER

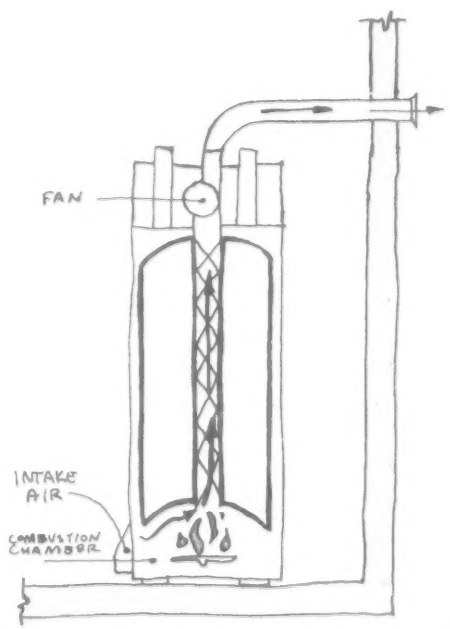

FIGURE 7·3 INDUCED DRAFT HOT WATER HEATER

7.1.9 Integrated Hot Water Systems

As modern houses have become so much more energy efficient, builders and manufacturers have questioned the need to have two entirely different systems supplying space heating and hot water. A number of integrated systems have recently been developed to respond to the need for simplicity and efficiency. Some of these systems employ hot water systems which draw their heat from the space heater (usually a hydronic boiler).

There are also systems which draw part or all of their space heating requirement through a coil in the domestic hot water tank. This approach has been used experimentally in a number of locations and worked successfully. It is a requirement that any space heating and hot water heating equipment used in Ontario have the appropriate approval of the governing agency or utility.

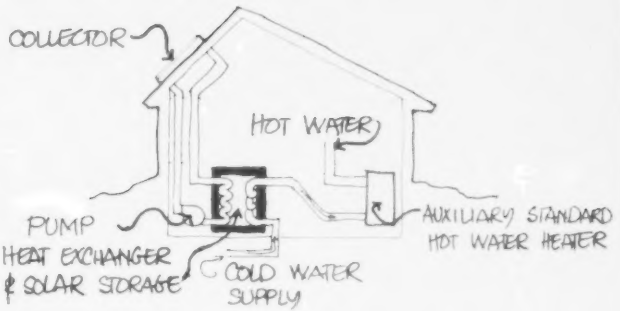

FIGURE 7·4
CLOSED LOOP SOLAR DOMESTIC HOT WATER SYSTEM

7.1.10 Solar Hot Water Heating Systems

There are two basic types of solar water heating systems in use. The first of these is a closed loop system usually containing an antifreeze fluid. This is circulated through the solar collectors, where it is warmed, and then to a heat exchanger where it warms the domestic hot water (Figure 7.4). The second type is a drain-back system in which the water is drained out of the solar collectors during periods of inactivity to prevent freezing. As with the closed loop system, water is circulated through the solar collectors where it is warmed and then to the storage tank. Domestic cold water is heated by passing through a heat exchanger located in the storage tank (Figure 7.5).

Only experienced designers and contractors should be retained to install a solar heating system.

Manufacturers offer 'packaged' solar domestic hot water heating systems that come complete with solar collectors, storage tanks, controls, valves, etc. If a system is required for a number of identical houses, manufacturers are usually willing to supply a custom-designed system to suit the specific requirements.

Caution: If fluids other than water are being circulated through the solar collectors, check to ensure that the system will comply with local plumbing codes, and will not pose a health hazard.

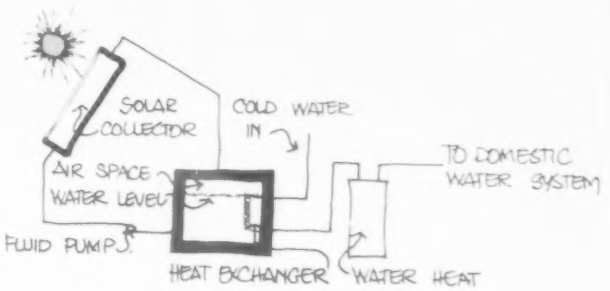

FIGURE 7·5
DRAIN DOWN SOLAR DOMESTIC HOT WATER SYSTEM WITH HEAT EXCHANGER

Section 8
Lighting and Appliances

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8.1 Lighting and Appliances

This section examines the types and locations of lighting fixtures that will reduce the energy consumption of a house. Guidelines are provided for selection of energy efficient appliances.

8.1.1 Recommendations

Lighting

- **Use fluorescent lighting instead of incandescent lighting wherever possible.**
- **Locate lights to illuminate specific areas. Indirect lighting should be avoided. Use wall mounted light fixtures where possible.**

Appliances

- **Choose appliances that make the most efficient use of their energy consumption.**
- **Use appliances that are just large enough to handle the loads imposed.**

8.1.2 Lighting

Fluorescent lamps are more efficient than incandescent bulbs in converting electrical energy to light, and should be used wherever possible. They produce three to four times as much light for the same energy rating as incandescents, and last twice as long. The most common sizes of fluorescent light used in residential construction are the 20-watt and 40-watt lamps.

In utility areas and workshops, the Standard Cool White lamp is recommended. For living areas, the more attractive Warm White lamp is preferred.

Fluorescent lighting fixtures should be shielded with plastic or glass lenses that reduce glare. These can be built into wall brackets (Figure 8.1), above counter areas (Figure 8.2) and beside the bathroom vanity mirror (Figure 8.3).

Light fixtures should be located as close to the point of use as possible (Figure 8.3). To encourage the occupant to turn lights off in unoccupied areas, each fixture should be provided with a convenient wall-mounted switch.

To promote lower light intensities, choose interior colour schemes that provide high reflectance values. Table 8.1 gives the reflectance of various building components recommended by Ontario Hydro.

Table 8.1
Interior Reflectance Values*

Surface	Reflectance Value (%)
Ceiling	80-90
Walls	40-60
Floors	25-45 (Typical)
Furniture	20-40 (Typical)

*These values can be provided by paint manufacturers.

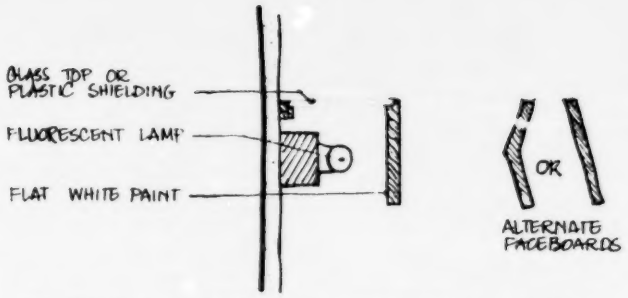

FIGURE 8·1 FLUORESCENT LAMP WITH WALL BRACKET

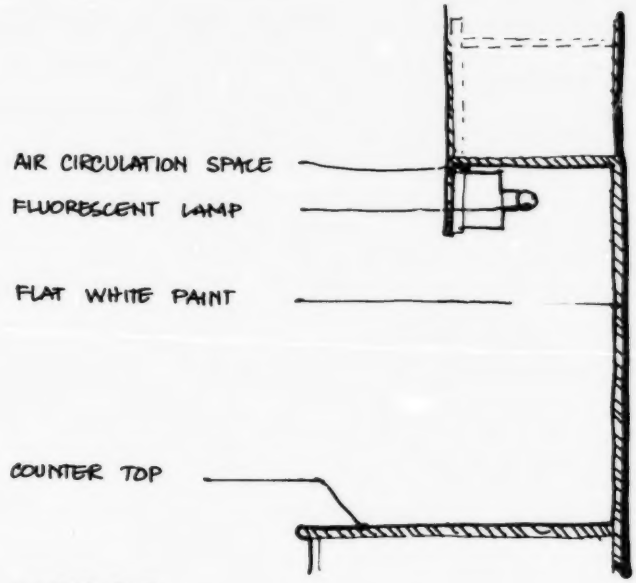

FIGURE 8·2
FLUORESCENT LAMP ABOVE COUNTER

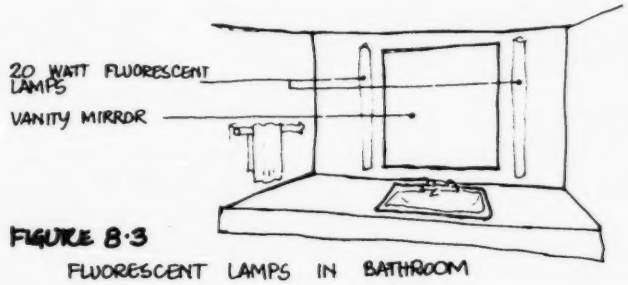

FIGURE 8·3
FLUORESCENT LAMPS IN BATHROOM

Although fluorescent fixtures and lamps are more costly than incandescents of equal wattage, their superior illumination and durability make them four times more economical.

8.1.3 Appliances

Appliances vary significantly in their energy requirements. In some energy efficient houses, the energy consumption by major appliances can represent as much as 15 to 20% of the total energy bill. The major household appliances and their estimated monthly consumption are shown in Table 8.2

It is important to realize that similar products made by different manufacturers may vary widely in their energy consumption. Table 8.3 provides a sample comparison for refrigerators. It is interesting to note that an automatic defrost refrigerator may be more efficient than some manual defrost refrigerators.

Recent passage of the Appliance Standards Bill by the U.S. Senate will see the issuance of mandatory minimum standards for eleven household appliances and heating and cooling equipment manufactured in the U.S. Similar standards are being investigated in Canada which could see more efficient products manufactured in Canada in the not-too-distant future.

In the interim, Consumer and Corporate Affairs Canada, through the Canadian Standards Association, has tested appliances for their energy consumption and is affixing labels (Figure 8.4) that allow the purchaser to compare the efficiency of different appliances. Provision of the smallest appliance capable of handling the loads will almost certainly save both money and energy.

Table 8.2
Monthly Consumption of Major Household Appliances

Appliance	Average Wattages watts	Monthly Consumption kWh
Food Freezer (non frost-free 0.43 m^3)	335	75
Food Freezer (frost-free 0.43 m^3)	425	90
Refrigerator Freezer (non frost-free 0.34 m^3)	300	100
Refrigerator Freezer (frost-free 0.34 m^3)	500	150
Range	12,500	100
Dishwasher	1,300	18
Clothes Washer	500	8
Clothes Dryer	4,800	80
Water Heater	4,500	500
Room Air Conditioner (6.3 MJ/hr)	935	60-400
Room Air Conditioner (9.5 MJ/hr)	1,400	90-600

Table 8.3
Monthly Energy Consumption for Three Refrigerator Types*

Refrigerator Type	Volume m^3	Monthly Energy Consumption** kWh	Consumption/ Volume kWh/m^3
Automatic Defrost	0.48	118	246
	0.49	177	361
Semi-automatic Defrost	0.48	79	165
	0.38	105	276
Manual Defrost	0.37	70	189
	0.40	102	255

** Models chosen, give a high and low range.
* The above table is derived from the 1979 Energy Guide Directory of Refrigerators (Consumer and Corporate Affairs Canada, and Canadian Standards Association).

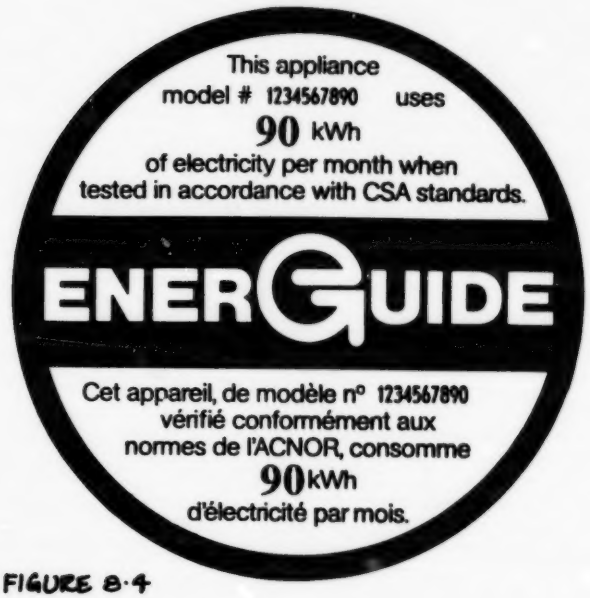

FIGURE 8·4

Section 9
Energy Efficiency In The Complete Dwelling

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Previous sections of the Guide have reviewed energy conservation options for the building shell, space heating, domestic hot water heating and lighting. The purpose of this section is to tell the builder:

- how to select the most suitable set of options considering his particular circumstances of location and construction costs, and
- what overall approaches may be taken to combine the options in the complete dwelling.

9.1 Recommendations

The following recommendations deal with:

1. how to select options
2. the focused approach, which concentrates on those building elements which are costly to upgrade after construction is complete, and
3. the balanced approach, which provides improved energy efficiency at about the same level of cost effectiveness for all main building elements.

9.1.1 Selecting the Options

- Select a range of building element improvements that you think would be desirable for your market. This can be done either by selecting options directly from Sections 4,5,6,7,8, or by developing others.
- Calculate how much each of these options will add to the price of the house. Make sure you include any overhead or mark up figures in your calculation.
- If you judge the price increase to be acceptable in your market, calculate the principle, interest, taxes and energy (PITE) offset and payback of each improvement (see Subsection 2.1.3).
- Check the results to make sure the price increase, PITE offset and the payback period are acceptable to your target market (see Section 10), then decide which options to use and whether to use the focused or balanced approach to combining them.

9.1.2 Focused Approach to Combining Options

- Building plans and designs incorporating some of the suggestions for internal layout, building form, and site planning discussed in Section 2 could be gradually worked in as designs are modified to suit lot sizes and meet other marketing requirements. These need not involve a cost premium.
- Using the estimated acceptable price premium, provide for the highest affordable performance level in construction of the exterior walls, and in the furnace and other mechanical and electrical equipment not easily improved after construction is completed. Consider upgrading windows and doors if usual installations have low performance compared with those discussed in Subsections 5.8 and 5.9.

- Design the basement and attic to simplify the addition of more insulation: provide at least 500 mm clearance between basement walls and the furnace, pipes, hot water heater, and laundry equipment; and provide for attic accessibility and edge baffles (see Subsection 5.6) to allow for added insulation.

- Provide options for improving the performance of other elements. These options should have about the same payback period as the basic improvements to the external walls.

- If optional improvements are not selected at the time of construction or sale, provide the purchaser with general advice on how to install them later.

9.1.3 Balanced Approach to Combining Options

- Start by modifying building plans and designs to include the recommendations for internal layout, building form and site planning in Section 2.

- Using these plans, upgrade standard practice to include the full range of construction options suggested in the earlier sections. These will include:
  - greater attention to installing the air/vapour barrier and insulation (see Section 5)
  - higher levels of insulation (see Section 5) for all parts of the building shell involving a range of improvements with approximately the same payback period
  - methods of air and moisture control (see Section 4)
  - improved mechanical and electrical equipment (see Sections 6,7, and 8).

9.2 Options for the Complete Dwelling

A wide range of energy conservation options have been presented and evaluated in the Guide. Builders must select the ones most suited to their own conditions.

The builder can select energy conservation options from those suggested in the Guide, or develop his own construction improvements. Selection will depend on the available labour and materials, as well as market preferences.

However, the options must be evaluated further in terms of actual costs and effectiveness, in terms of PITE offset and payback as a means of ensuring buyer acceptance. The builder must first confirm the purchase price premium for each of the improvements.

The builder will then wish to review the costs, PITE offset and payback period for options for each of the elements and select those which he feels will best suit his market. At the same time he can decide whether he wants to upgrade just one or two elements such as walls and furnaces, or whether he feels his market will accept the price premium for improvements in other elements as well, such as ceilings and foundation walls. Logical approaches to making this decision are described below.

9.3 Combining the Options

There are two basic approaches to combining the various options: the focused approach and the balanced approach.

9.3.1 The Focused Approach

The focused approach concentrates on the most effective improvements. Using this approach the most logical place to provide energy-saving construction features is where they would be difficult or costly to put in later. This includes exterior walls and upgraded space heating or domestic hot water heating equipment. Other energy conservation options should be included if they are cost effective and do not increase the dwelling purchase price beyond buyer acceptance.

This approach may be justified when a high level of insulation in all building elements (measured in terms of payback period) will increase the initial cost of the houe more than buyers will accept. It may also be justified when the most effective way of reaching a high degree of energy efficiency (especially in lower cost housing) is to provide a high level of performance in some elements, and let the homeowner take advantage of potential government programs and his 'do-it-yourself' skills to bring other building elements to the same level. A logical marketing strategy, however, would involve providing upgrading of these other building elements as an option at the time of purchase (see Section 10).

9.3.2 The Balanced Approach

In the balanced approach, a number of energy-saving features with similar payback periods are provided. The degree (and cost) of upgrading can be varied to suit the market — a payback period of as little as three to five years, say, in the lower price market, and eight to ten years, or even longer, for higher priced housing (see Section 10). The payback periods for mechanical and electrical equipment may vary from those of other building elements, even in the balanced approach due to the different nature of these elements (see Sections 6,7 and 8).

9.4 Price Premium by Dwelling Unit Type

An important factor in introducing energy efficient features is the increase in purchase price. This will vary according to the type and size of the dwelling. Experience with the R-2000 Home Program and Ontario Ministry of Energy Demonstration Projects in Ontario indicated that houses constructed for high levels of energy efficiency can result in a reduction of space heating energy use from conventional designs by up to 75%. This is achieved for a price premium range of from 2-10% for the more common types of single family, semi and row housing dwellings.

Section 10
Marketing Energy Conservation Features In New Housing

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The purpose of this section is to review various marketing principles and recommend approaches that the builder can take to help him market the energy efficient features that he has incorporated in his dwellings.

10.1 Broad Recommendations

- **After making the effort to determine what energy conservation features to provide, publicize them strongly and take the time to explain them to prospective buyers. Ensure marketing and sales personnel are technically knowledgeable.**

- **Remind prospective buyers that energy conservation features mean immediate real savings in energy costs which can ultimately result in net savings in ownership costs.**

- **The focused approach is the most flexible way of providing energy efficiency because builders can provide optional features such as adding more ceiling insulation at the time of purchase.**

- **Stress to prospective buyers that an energy efficient house is a well built quality product.**

- **Make every effort to persuade lending agencies that the extra purchase price for energy conservation features should be included in the allowable mortgage amount. Some lenders already take into consideration energy savings as offsetting principal and interest.**

- **Builders should consider three main markets when deciding on what approach to take in offering energy conservation features:**

  - first-time buyers

  - move-up buyers

  - move-down buyers

10.2 General Marketing Principles

Earlier sections have indicated that there is an initial price premium for most of the energy conservation options. Because the home purchaser must decide what price he is prepared to pay for energy efficiency, it is suggested that cost effectiveness be described in terms of net change in principal and interest payments due to energy savings.

Home buyers are interested in saving energy, but builders can encourage greater acceptance, and ultimately reduce the growth in energy demand, by promoting and providing improved construction.

Marketing energy conservation will also help to sell homes as buyers realize that energy efficiency:

- pays increasing dividends as energy prices continue to rise,

- provides a more comfortable living environment, and,

- improves resale value.

An understanding of these benefits can therefore be a strong incentive to purchase homes with energy saving features.

Experience in marketing of energy efficient features in housing has become more common in the last few years. A number of principles should be understood by the builder to help him organize his marketing approach:

- Housing type, location and price continue to be the primary factors for dwelling selection. Energy efficiency and other features are clearly considered less important.

- Buyer awareness of the importance of energy conservation, particularly in the home, is increasing due to steadily rising fuel prices and predictions regarding the availability of domestic and foreign energy supplies.

  - Energy-saving options received the highest rating in a survey of home buyers in Western Canada, where heating costs are among the lowest in the country.

  - Energy efficient homes are selling in a wide price range to all categories of buyers.

- Buyers of all ages and income ranges are interested in energy conservation features. Those at the lower income scale, however, are often reluctant to pay a premium for these features, because their major concern is being able to afford monthly mortgage payments for basic shelter. Builders should offset this concern by addressing principle, interest, taxes, and energy costs in their marketing approach.

  - The inside living space and appearance remain extremely important. Reduction of space and/or the quality of visible materials and finishes to offset any cost premium for energy-saving features may meet with buyer resistance. By considering the idea of payback period for energy efficient features it is not necessary to reduce floor area or quality.

  - Buyers of the most expensive houses appear to be more energy conservation conscious and appear to accept higher costs for such features as part of the overall price.

  - Three specific market sectors, first-time buyers, move-up buyers, and move-down buyers (see Subsection 10.3), vary in their degree of acceptance of energy efficient features.

These principles will continue to evolve as energy conservation increases in importance and as more buyers gain a greater knowledge and understanding of the value of energy efficiency.

10.3 Three Specific Market Sectors

The addition of energy efficient features in builders' homes reduces operating costs, thereby, at least partially offsetting the increased down payment and/or monthly mortgage payments. The importance of this characteristic to the various market sectors is described in more detail below.[1]

10.3.1 First-Time Buyers

First-time buyers are usually young couples with one or two young children. Both husband and wife may work, but if the wife works, daycare costs will reduce the total family income. Generally they cannot afford large carrying and operating costs. This group has little or no first-hand experience in operating and managing a dwelling unit.

They generally view their first purchase as a transitional step until such time (usually three to five years) as they can afford a more luxurious home in a more suitable location, and one that is large enough to raise older children. Their first home purchase must provide basic shelter and cannot contain too many extras, including costly energy efficient features with a long term payback. At the same time, this group would like improved energy conservation and reduced operating costs.

The builder can appeal to this market sector in the following ways:

- Provide them with a compact dwelling unit with simple form and internal layout features as described in Section 2. These features need not involve any price increase.

- Offer basic upgrading of energy efficiency by concentrating the improvements in the exterior walls. Point out that this provides performance beyond code requirements. Indicate that the remaining areas of upgrading can be done easily later, in some cases as a 'do-it-yourself' project for the owner. Or offer upgrading of these features as optional extras to be built in during construction or added at the time of sale.

- In a highly competitive market where prices must be kept as low as possible, select energy efficient features that will totally offset increases in any additional principal and interest payments starting in the first years, and explain the meaning of this to potential purchasers in relation to their likely period of ownership. In particular, note that the reduction in yearly heating costs is greater than the increase in mortgage payments, and that this difference will continue to grow as fuel prices rise. Low energy houses are also eligible for a 2% increase in their gross debt service ratio for the purchasers.

[1] Note that there may be variations within each of these market sectors, but in general terms their description is as indicated in 10.3.1, 10.3.2 and 10.3.3.

[2] This applies only if the lender recognizes the extra prices of the conservation features by increasing the mortgage amount, and if the builder has selected cost-effective features.

10.3.2 Move-Up Buyers

Move-up buyers are generally couples with older children. They have greater financial means than first-time buyers. Both husband and wife are at a higher career level than as first-time buyers, with little or no daycare costs if the children are in school. More importantly, move-up buyers often have substantial equity from their previous home.

They anticipate staying in their new home at least until their children have grown up, often eight to ten years or longer. They want comfort, convenience and expect to pay for it, partly because they may have less time for 'do-it-yourself' projects. They have an understanding of the investment value of their home, and generally prefer large single family houses. Their experience with their first dwelling has taught them to appreciate the significance of operating costs and they will consider the benefits of a wide range of energy efficient features. Consistent with their anticipated length of time of ownership, they may be willing to consider a longer payback for these features (i.e., 8 to 10 years). Buyers of dwellings in the higher price ranges will be less concerned about payback and more interested in obtaining highest quality including high energy efficiency. This group is more aware of energy cost as it relates to home heating bills. The builder can offer this group a much broader range of energy efficient options:

- Offer a very high level of energy efficiency. This may be in the form of the balanced approach as a total package, or it may consist of high performance exterior walls and a series of optional features.

- The buyers' anticipated length of time of ownership suggests that these dwellings should be provided with features beyond code requirements having a payback of eight to ten years (or longer for houses in the upper price range).

- Explain the PITE concept, and, using Figure 1.3 as a guide, discuss how current energy costs may change over the next few years.

10.3.3 Move-Down Buyers

Move-down buyers are generally couples or individuals whose children have grown up and left home. This group does not generally expect its income to keep rising and wishes to avoid reducing capital saved. Move-down buyers have significant equity from previous home ownership.

This group, like the move-up buyers, also anticipate a relatively long stay in their home compared to first-time buyers. They also prefer comfort and convenience with the added advantage of lower operating costs and less maintenance work than the larger home they are leaving. This group is also very conscious of the housing unit as an investment. Their preference is for a smaller (but not necessarily cheaper) single family house, semi-detached unit, or row house. The idea of living on a relatively fixed income after retirement improves the likelihood of acceptance of energy conservation features. However, the move-down buyer may be less interested in 'do-it-yourself' energy efficiency improvements because of his or her increased age.

The builder can provide and sell these features as follows:

- Provide energy efficient features in the overall home package, or build a high level of insulation into the exterior walls and offer upgrading of other elements as options. Point out the increased cost and effort of adding options at a later date.
- Select features with an eight to ten year payback (or longer if the buyer will accept).
- In contacts with potential buyers, try to relate the energy efficiency improvements to features of their large present home, to emphasize the savings of going to a more compact and efficient dwelling.
- Be prepared to comment on trends in the price of energy, and the importance of energy costs for home buyers with stable incomes.
- Point out the effect of the energy saving features on resale value.

Table 10.1 summarizes the alternative approaches for combining the options for all 3 market sectors.

Table 10.1 Approaches for Combining Options for the Three Market Sectors

Approach	First-Time Buyers	Move-Up Buyers	Move-Down Buyers
Focused approach with advice for later improvements	•		
Focused approach with options for other elements at the time of construction/sale	•	•	•
Balanced approach		•	•

10.4 General Marketing Approaches

In addition to considering the three broad market sectors reviewed above, builders should take a variety of general marketing steps to sell energy efficient features.

10.4.1 Local Factors Affecting Energy Consumption

- Be aware of such information as degree days in the local area (available in local codes), wind direction and speed, and frequency of periods of particularly cold weather.
- Be aware of local unit cost for the main sources of energy, availability, supply, and short term projected cost growth rates.
- Note the extent of publicity given in local news media and other sources available to potential buyers regarding rising energy costs, potential shortages, and other general energy predictions. It is against this background that buyers will be considering the extent they wish to invest in energy efficiency in their new home.

10.4.2 Buyer Characteristics

- Learn and understand the characteristics of the target market: age, income, family size, lifestyle, level of education.
- Relate these to the three main market sectors discussed above. Determine and be prepard to discuss the criteria which energy efficient features must meet (for example, net PITE savings, payback period, maximum dollar amount, appeal to various levels of understanding).

[3] This information can be obtained in publication NRCC No. 15556 from
Division of Building Research
National Research Council of Canada
Ottawa, Ontario K1A 0R6

10.4.3 Other Marketing Experience

- Through local builders' associations, determine what the experience has been in the area with respect to introducing energy efficient features: what features, who is buying, estimated price premium, owner reaction after one or two heating seasons.
- Be aware of the same information on a regional/national or North American level through periodicals for the housing industry, and builders' associations.

10.4.4 Selection of Features

- Consider the full range of energy efficient features including choice of dwelling unit type, internal layout, site planning, landscaping and building element details.
- Calculate the price premium over a similar dwelling which meets minimum requirements of the building code.
- Decide on whether to use the balanced approach, upgrading all major building elements to the same general payback length, or the focused approach, emphasizing elements not easily improved after construction, such as walls and space heating equipment. The focused approach should be combined with the option of upgrading the other elements at the time of construction or sale, or with suggestions for later improvements when the owner can afford them
- Relate PITE analysis and payback period to the appropriate market sector. At the upper end of the price range, PITE offset and pay-back time will not be as important as for the more modestly-priced home.
- In selecting energy efficient features, remember that the dwelling must first meet the basic needs and desires of the potential buyer. Do not rely on improvements to energy efficiency or other innovations to compensate for essentials that are not provided.

10.4.5 Presenting the Features

- Highlight the fact that the dwelling contains energy efficient features beyond requirements of the local or provincial building code.
- Emphasize that the dwelling form, materials and workmanship are based on what buyers have indicated they want.
- If the optional approach is used, explain that the buyers have a choice in deciding what energy efficient features they wish to purchase, now, and what features they want to add later. Point out that the buyer will save money if he or she purchases all of the available options at the time of construction, as improvements contracted after are generally more costly.
- Provide mock-ups of some features: for example a wall section, or a ceiling section (Figure 10.1). These can be displayed in the model home or sales office. Use large labels attached to or near these features in the model home. Or use display panels and large labelled diagrams to illustrate energy

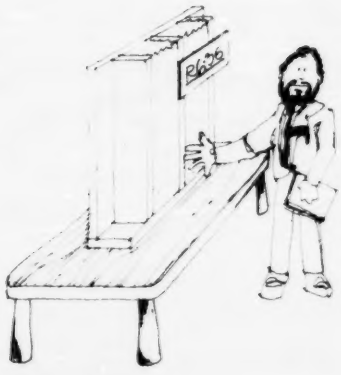

FIGURE 10·1

efficient features (Figures 10.2, 10.3). These can be displayed in the sales area and be included in promotional literature. In all cases note the fact that insulation materials have been accepted by CMHC.

- Be prepared to explain what the features are, their functions, why they are important, and the PITE offset concept (if applicable). Also explain that the energy cost savings will continue long after the cost premium has been paid off, thereby making the home a good investment for the first buyer as well as subsequent buyers.

- Indicate how careful planning and design has resulted in improved building form, internal layout and site planning that helps reduce energy consumption at no additional cost to the buyer.

- Be sure that sales staff or real estate agents are familiar with and understand the technical features, can point them out and explain them.

- If you are part of a program endorsed by government agencies, establish credibility by mentioning the agencies which suppport your program.

- Explain to prospective buyers some of the environmental advantages (user benefits) to an energy efficient house, such as, even heating (no stratification), a draft-free environment, continuous controlled fresh air circulation, and an improved environment for allergy prone people.

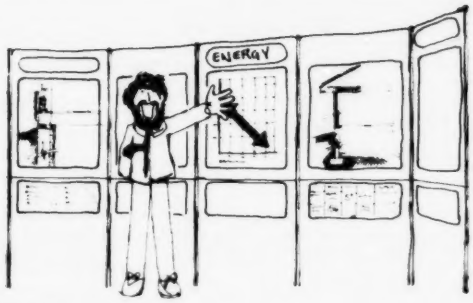

FIGURE 10·2

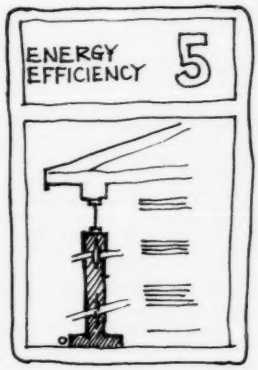

FIGURE 10·3

10.4.6 Owner's Manual

- To emphasize the serious study and research put into the design and construction, develop a home-owner's guide to operation and maintenance, and will serve to instruct the occupants on how to achieve the most benefit from energy efficient features. It could also contain information on how to prolong the life of the home through timely and proper maintenance.

- This guide should contain such items as:

  - suggestions for habits which will ensure the highest level of energy efficiency

  - reminders on humidity control and winter ventilation

  - information on operating and servicing all major appliances, especially the space heating equipment, hot water heater, and ventilation system

  - landscaping suggestions to reduce heat loss in winter and heat gain in summer

  - recommended for maintenance of exterior and interior surfaces, and doors and windows

[4] Use latest editions, modified to give up-to-date advice.

- a suitable folder for the warranty, insurance policies, and a file pocket for keeping records on sch items as energy costs, property taxes, insurance premiums, and mortgage payments

- publications by Energy, Mines and Resources Canada: 'The Billpayer's Guide to Furnace Servicing', '100 Ways to Save Energy in the Home', and 'Keeping the Heat In'.

- publications by the Ontario Ministry of Energy, such as 'A House For All Seasons', and 'The Right Home For You'.

10.4.7 Reaction of Potential Buyers and Purchasers

- Take the opportunity when talking with potential buyers to discuss their opinions, interests, and understanding related to the energy efficiency features, including the manner in which they are presented.

- Review reactions to the features with selected purchasers after occupancy through at least one heating season.

- Based on these findings, begin planning the next round of energy efficient features and the related marketing effort.

Appendices

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APPENDIX A
HEAT LOSS AND PAYBACK CALCULATIONS FOR BUILDERS

This appendix provides data and a method which will permit builders to carry out their own calculations of annual heating costs and savings due to upgrading. This will allow the evaluation of options. The method demonstrated in the following example is based on a number of simplifications and assumptions but is sufficiently accurate for the intended purposes.

In order to permit the evaluation of options it is necessary to go to greater detail than has been presented thus far. For example it is necessary to calculate the reduction in RSI values due to heat loss through framing.

It is also necessary to deal separately with the below grade, above grade and header portions of the foundation walls.

In order to use this method the builder needs to know the following:

- dimensions of the house
- materials used in the base house and in the proposed upgraded house
- cost of the proposed upgrading
- local price of the relevant energy source
- degree days of the site[1]

A.1 WORKED EXAMPLE

For simplicity we will work with a two-storey detached house of simple rectangular shape with no insets or projections. Details of the house are shown below. The upgraded house will include improvements to the building shell as shown, and an induced draft gas furnace (Figure A.1).

OTHER GIVEN DATA: Storeys – 2
Plan Dimensions – 9.0m × 9.56m

Window Area in:	
Basement	4.0m^2
1st Storey Walls	12.0m^2
2nd Storey Walls	8.0m^2
Door Area	4.0m^2
Heating	base case: gas furnace with conventional pilot light, upgraded house: induced draft gas furnace
Stud Spacing	400mm o.c. 1st storey 600mm o.c. 2nd storey
Windows	double-glazed – RSI 0.3
Doors	insulated steel – RSI 1.0
Air Change	assumed to be an effective 0.3 air changes per hour before upgrading and 0.2 air changes per hour with heat recovery after upgrading.
Location	Oshawa, Ontario 4130°C Degree-days
Cost of Gas	\$0.22/m^3 \$0.006/megajoule

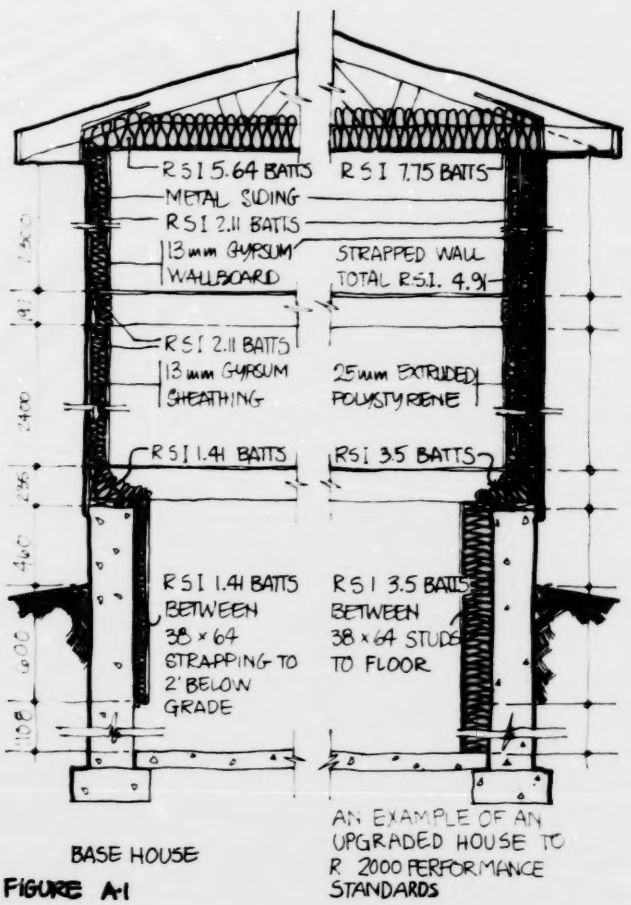

RSI 5.64 BATTS
METAL SIDING
RSI 2.11 BATTS
13mm GYPSUM WALLBOARD
RSI 2.11 BATTS
13mm GYPSUM SHEATHING
RSI 1.41 BATTS
RSI 1.41 BATTS BETWEEN 38 × 64 STRAPPING TO 2' BELOW GRADE
RSI 7.75 BATTS
STRAPPED WALL TOTAL RSI. 4.9
25mm EXTRUDED POLYSTYRENE
RSI 3.5 BATTS
RSI 3.5 BATTS BETWEEN 38 × 64 STUDS TO FLOOR
BASE HOUSE
AN EXAMPLE OF AN UPGRADED HOUSE TO R 2000 PERFORMANCE STANDARDS

FIGURE A-1

[1] Degree-day values for 78 metropolitan areas and large urban centres across Canada are given in Table B1 (average for 1951 to 1980). Values for other locations can be found in *Climatic Information for Building Design in Canada*, Supplement No. 1 to the National Building Code, NRCC No. 15556, from Division of Building Research, National Research Council, Ottawa, K1A 0R6.

A.1.1 Step 1 – Calculate Areas

Perimeter = $2 \times (9.0 + 9.56) = 37.12\text{m}$
Ceiling Area = $9.0 \times 9.56 = 86.04\text{m}^2$
2nd Storey Wall Area = $2.300 \times 37.12 = 85.38$
minus windows $- \underline{8.0}$
$= 77.38\text{m}^2$

2nd Storey Floor Header Area = $0.197 \times 37.12 = 7.31\text{m}^2$

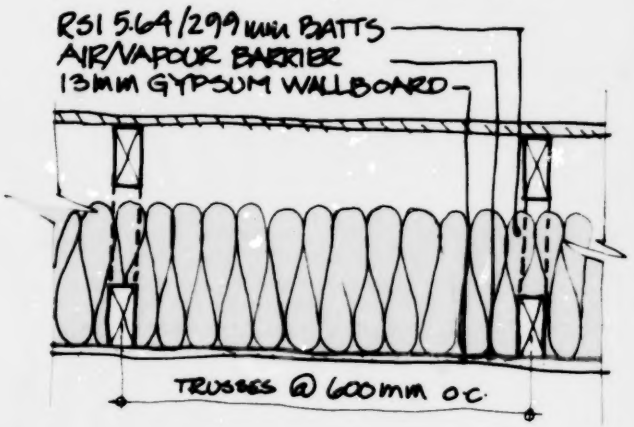
1st Storey Wall Area = $2.400 \times 37.12 = 89.09$
minus windows $- 12.0$
minus doors $- \underline{4.0}$
$= 73.09\text{m}^2$

1st Storey Floor Header Area = $0.235 \times 37.12 = 8.72\text{m}^2$

Above Grade Foundation Wall Area = $0.460 \times 37.12 = 17.08$
minus windows $- \underline{4.0}$
$= 13.08\text{m}^2$

A.1.2 Step 2 – Calculate RSI Values

RSI values for individual materials are found in Table B.2. Rather than carry out all the repetitive calculations here, only examples are shown.
Base Case Ceiling:

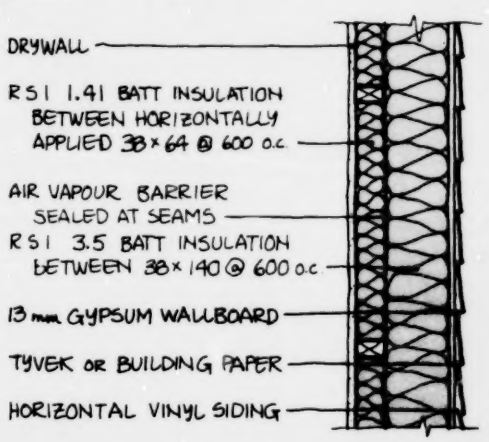


	RSI through insulation	RSI through truss bottom chord
Bottom air film	0.105	0.105
Gypsum 0.0062x13	0.081	0.081
Framing 0.0087x89	–	0.774
Insulation	5.64	$\frac{210}{299} \times 4.93 = 3.462$
Top air film	0.030	0.030
	5.856	4.452

With framing at 600mm o.c., the framing represents about $\frac{38}{600} = 7\%$ of the area. For every 100m^2 of ceiling area, there would be 7m^2 with framing and 93m^2 without.

Therefore adjusted RSI $= \dfrac{100}{\frac{93}{5.856} + \frac{7}{4.452}} = 5.73$

Upgraded 2nd Storey Wall:

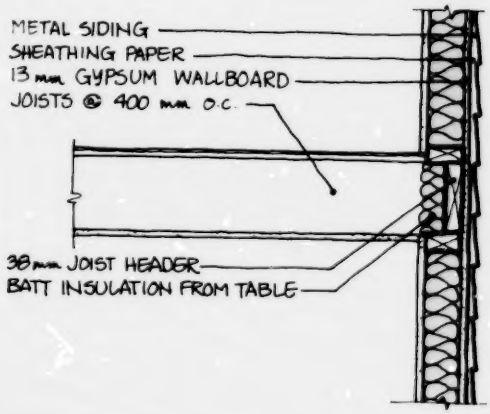

DRYWALL
RSI 1.41 BATT INSULATION BETWEEN HORIZONTALLY APPLIED 38 x 64 @ 600 o.c.
AIR VAPOUR BARRIER SEALED AT SEAMS
RSI 3.5 BATT INSULATION BETWEEN 38 x 140 @ 600 o.c.
13 mm GYPSUM WALLBOARD
TYVEK OR BUILDING PAPER
HORIZONTAL VINYL SIDING

	RSI through insulation	RSI through studs
Outer air film	0.030	0.030
Metal siding	0.123	0.123
Sheathing paper	0.011	0.011
Batts	3.5	–
Framing 0.0087 × 140 = 1.218	–	1.218
Batts	1.2	–
Strapping 0.0037 × 64 = 0.5568	–	0.5568
Gypsum 0.0062 × 13 = 0.081	0.081	0.081
Inner air film	0.120	0.120
	5.335	2.1398

For walls the percentage of framing is somewhat higher than for ceilings with the same framing spacing due to the presence of window and door framing, doubled studs at partition intersections, etc. With 600mm spacing, each 100m^2 of wall will have about 11m^2 with framing and 89m^2 without. With 400 mm spacing, the proportions would be about 19m^2 and 81m^2 respectively. In this case, the interior strapping will not affect this relationship.

Therefore adjusted RSI $= \dfrac{100}{\frac{89}{5.335} + \frac{11}{2.1398}} = 4.58$

Base Case 2nd Storey Floor Header:



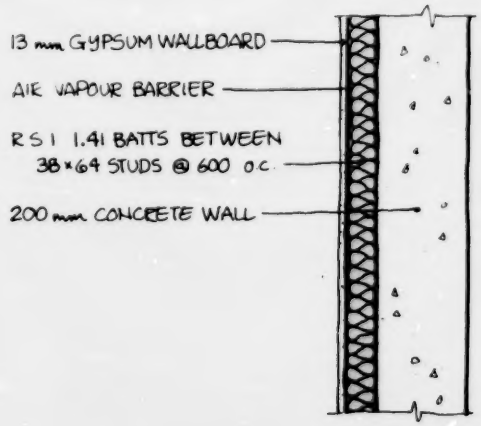
Heat loss through the header area is quite complicated and correcting for the interruption of the insulation by the joists can be quite tedious. The following table is therefore provided to relate the RSI value of the batts added to the header area to their final, adjusted value. It also makes some allowance for loss through the subfloor.

Table A.1 – Adjusted RSI Values For Joist Header Areas

RSI Value of Batt	Adjusted RSI Value
1.41	1.17
1.76	1.47
2.11	1.67
2.47	1.84
3.52	2.80
4.93	3.94

Outer air film	0.030
Metal siding	0.123
Sheathing paper	0.011
Gypsum 0.0062 × 13	0.081
Header 0.0087 × 38	0.331
Insulation (from table)	1.67
Inner air film	0.120
	2.366

Foundation Wall Above Grade:



	RSI through Insulation	RSI through Studs
Outer air film	0.030	0.030
Concrete 0.00045 × 200 = 0.090	0.090	0.090
Batts	1.41	–
Framing 0.0087 × 64 = 0.557	–	0.557
Gypsum 0.0062 × 13 = 0.081	0.081	0.081
Inner air film	0.120	0.120
	1.731	0.878

Therefore adjusted RSI = $\dfrac{100}{\frac{89}{1.731} + \frac{11}{0.878}} = 1.56$

Base Foundation Wall Below Grade:
Here, rather than an RSI value, we will work out a heat loss factor for a 1 metre wide vertical strip. This is similar to the factors given in Tables 4.1 and 4.2 but here it will apply to the below grade portion only.

From Figure B.2 for RSI 1.41 added to 600mm below grade,
Heat Loss Factor = 0.67 w/°C – m
For 900mm below grade,
Heat Loss Factor = 0.58 w/°C – m
Interpolating, for 682mm below grade,
Heat Loss Factor = 0.65 w/°C – m

A.1.3 Step 3 – Calculate G Factors

The G factors represent overall heat loss factors (HLF). These are determined for conduction and convection (air change).

Conduction Through Building Shell

Using the procedures illustrated above all RSI values for both the base and upgraded houses can be calculated and tabulated as follows:

	Base House			Upgraded House	
	Area (m^2)	RSI (m^2 °C/W)	A/RSI (W/°C)	RSI (m^2 °C/W)	A/RSI (W/°C)
Ceiling	86.04	5.64	15.25	7.88	10.92
2nd Storey Walls	77.38	2.28	33.94	4.58	16.89
2nd Storey Header	7.31	2.37	3.08	4.55	1.61
1st Storey Walls	73.09	2.12	34.48	4.58	15.96
1st Storey Header	8.72	1.87	4.66	3.41	2.56
Above-grade Foundation	13.08	1.56	8.38	2.68	4.88
Windows	24.00	0.30	80.00	0.30	80.00
Doors	4.00	1.00	4.00	1.00	4.00
	Perimeter (m)	HLF (W/°C-m)	Perimeter × HLF	HLF (W/°C-m)	Perimeter × HLF
Below-grade Fdn.	37.12	0.65	24.13	0.24	8.91
TOTALS			207.92 W/°C		145.73 W/°C

Air Change

The house volume is approximately the sum of all the vertical dimensions in Figure A.1 multiplied by the plan area of the house; i.e.
$7.38 \times 9.0 \times 9.56 = 635 m^3$
Therefore volume changed per hour = $635 \times 0.3 = 191 m^3$ for the base house
$635 \times 0.2 = 127 m^2$ for the upgraded house.
Each cubic metre of outside air which enters the house requires 0.335 watt-hours of energy to heat it 1 Celsius degree.
Therefore, air change heat loss = $191 \times 0.335 = 63.99$ W/°C for base house
$127 \times 0.335 = 42.54$ W/°C for the upgraded house.
Therefore the total heat loss factors (G factors) for the house, before and after upgrading, are as follows:
Base house: G = 207.92 + 63.99 = 272 W/°C
Upgraded house: G = 145.73 + 42.54 = 188 W/°C

This can also be expressed in megajoules (MJ) per hour per °C by multiplying by the factor 3.6×10^{-3}.
Therefore –
Base house: $G = 272 \times 3.6 \times 10^{-3} = 0.979$ MJ/hr-°C
Upgraded house: $G = 188 \times 3.6 \times 10^{-3} = 0.677$ MJ/hr-°C

What these factors mean is that if the temperature outside the base case house is 1°C colder than the inside temperature, then, every hour 0.979 megajoules of energy will flow outward through the roof, walls, windows, doors, and in the infiltration/exfiltration of air. If the outside temperature is 10°C colder then 9.79 megajoules will flow out in an hour, etc.

A.1.4 Step 4 – Calculate Annual Heating Costs and Savings

The degree-day value for a site provides a measure of how cold it is and for how long. Multiplying the G factor for the house by the degree-days gives an approximation of the gross energy loss from the house.
Therefore for the base house:

Gross Energy Loss = 0.979 × 4130 × 24 (to convert degree-days to degree-hours)
= 97,000 MJ

However as discussed in Subsection 2.1 only part of this loss is made up by the furnace. The rest, the "free heat", comes from the sun, from appliances and from the occupants themselves. Although the amount of free heat varies from household to household, a typical value would be 26,000 megajoules per year.
Therefore for the base house:

Energy supplied by furnace = 97,000 – 26,000
= 71,000 MJ

However the furnace, according to Table 6.1, is only 60% efficient on a seasonal basis. Therefore more energy is purchased than is actually supplied to the house.

$$\text{Therefore purchased energy} = \frac{71{,}000}{0.60}$$
= 118,333 MJ
and annual heating cost = 118,333 × 0.006
= $710

Similarly, for the upgraded house:

Gross Energy Loss = 0.677 × 4130 × 24
= 67,100 MJ

Energy supplied by furnace = 67,100 – 26,000
= 41,110 MJ

Ignoring, for the moment, the expected higher efficiency of the induced draft furnace in the upgraded house,

$$\text{Purchased energy} = \frac{41{,}100}{0.60}$$
= 68,500 MJ

Annual heating cost = 68,500 × 0.006
= $411

Saving due to upgrading shell = $710 – $411
= $299

To this is added the savings expected from the higher efficiency of the induced draft furnace. Table 6.2 indicates that this varies between 20-25%. Since this house is in a relatively mild area, we will use the lower figure.

Therefore TOTAL SAVINGS = $299 + $82 = $381.

A1.1.5 Step 5 Calculate Increased Capital Cost

This total annual savings of $381.00 means a monthly savings of about $32.00. This extra $32.00 per month towards an 11% mortgage amortized over 25 years can carry an extra $3,200.00 on the initial purchase price of the house. The builder is in the best position to calculate his own price and by working through this illustrated methodology can determine how to most cost-effectively upgrade from Building Code Standards.

A.2 NOTES ON THE HEAT LOSS CALCULATION METHOD

The method presented here was developed by Scanada Consultants Limited. It is based on standard methods such as ASHRAE or HRAI but modified empirically to fit the results of a number of field studies of actual energy consumption in houses. Its unique features concern air change, free heat, and below grade heat losses.

A.2.1 Air Change

The available data on the amount of air change experienced by houses is very limited. However what is available tends to indicate that ⅓ of an air change per hour is both a typical figure for modern, well insulated houses and a safe lower limit below which humidity problems will tend to appear. Thus even if the building shell were to be substantially tightened as recommended in Subsection 5.1 so that accidental air change was reduced below ⅓ air change per hour, it would be necessary to bring total air change back up to or near this level by the introduction of controlled ventilation. Government standards are presently recommending that fresh air for the ventilation of rooms and spaces in buildings of residential occupancy be provided at a rate of at least half an air change per hour by a combination of natural and mechanical ventilation in all new houses. Recent studies have also shown that, whereas insulating a previously uninsulated house can substantially improve its airtightness, going from "well insulated" to "better insulated" has no appreciable affect on airtightness.

Thus this method, as applied to new housing, makes no allowance for improvements in airtightness and, at the same time, saves time and effort by eliminating the elaborate crackage calculations of other methods.

No doubt new houses are being built that far exceed this rate of ½ air change per hour, but this is usually due to poor construction. It is impossible, using calculations alone, to predict the occurrence of such faults or to measure their effect.

A.2.2 Free Heat

The calculation method recognizes that, for a given household and basic house design and orientation, the heat contributed by appliances, occupants and the sun remains essentially constant, no matter what the gross heat loss of the house, and remains constant in absolute terms rather than in terms of a percentage of gross heat loss. Other methods often use a constant modifying factor for the degree days in calculating both base case and upgraded case heat losses and this tends to understate savings. This method does not modify the degree days but subtracts a constant amount from both the base and upgraded gross heat losses. If it is only desired to predict savings, as opposed to heating bills, then it is not necessary to assess the amount of free heat with much accuracy since it drops out of the savings calculation.

The above should be qualified to some extent. If a house design is substantially upgraded, then in the early fall and late spring the daily free heat contribution may well exceed the gross daily heat loss and it will be necessary to open windows to prevent the temperature from rising. In other words some of the free heat will be "spilled" and, in terms of its contribution to annual heating requirements it will not remain exactly constant. Within the range of upgrading covered by this Guide, this effect is likely to be very small and keeping the free heat constant is sufficiently accurate. This would not be true, however, for very large differences between the base and upgraded gross heat losses – where the latter is, say, less than half of the former.

A.2.3 Below Grade Heat Losses

The method used here is based on a model of below-grade heat losses developed by the National Research Council a number of years ago (Boileau, G.G. and Latta, J.K., "Calculation of Basement Heat Losses", National Research Council of Canada, Division of Building Research, NRC 10477, Dec. 1968). Recent field studies have indicated that this model is generally correct but, since it was originally developed for calculating instantaneous heat losses for design purposes, modifications have been introduced to adapt it to the calculation of annual heat losses.

Among these modifications is one that takes into account the fact that basement temperatures tend to be lower than those in principal living areas. For split-level houses and other styles where some of the principal living area is below grade, and higher temperatures are therefore maintained there, this method may tend to understate heat losses.

Appendix B
Data for Heat Loss Calculations

Table B.1
Degree Days of Selected Urban Areas

Urban Area	30 YEAR NORM. 1951-1980 Degree Days Below 18°C	Urban Area	30 YEAR NORM. 1951-1980 Degree Days Below 18°C
Barrie	4470	Peterborough	4410
Beileville	4129	Port Alberni	3151
Brandon	6046	Portage la Prairie	5837
Brantford	3922	Prince Albert	6559
Brockville	4229	Prince George	5376
Calgary	5328	Prince Rupert	3987
Charlottetown	4608	Red Deer	5623
Chatham (Ont.)	3607	Regina	5901
Chicoutimi	5435	Rimouski	5260
Corner Brook	4750	St. Catharines	3664
Cornwall	4418	St. Hyacinthe	4557
Dawson Creek	6231	Saint John	4768
Drummondville	4702	St. John's	4787
Edmonton	5484	St. Thomas	3985
Flin Flon	6719	Sarnia	3952
Fredericton	4730	Saskatoon	6063
Granby	4604	Sault Ste. Marie	5031
Guelph	4304	Sept-Iles	6154
Halifax	4123	Shawinigan	5047
Hamilton	3772	Sherbrooke	4871
Kamloops	3751	Sorel	4672
Kelowna	3612	Stratford	4403
Kenora	5938	Sudbury	5446
Kingston	4246	Swift Current	5471
Kirkland Lake	6113	Sydney	4541
Kitchener	4146	Thetford Mines	5311
London	4132	Thunder Bay	5768
Medicine Hat	4868	Timmins	6225
Moncton	4685	Toronto	3646
Montreal	4401	Trail	3573
Moose Jaw	5435	Trois Rivieres	4993
Nanaimo	3007	Truro	4532
Niagara Falls	3661	Val d'Or	6199
North Battleford	6071	Vancouver	2924
North Bay	5348	Vernon	3975
Oshawa	3968	Victoria	3031
Ottawa/Hull	4634	Welland	3733
Owen Sound	4236	Windsor (Ont.)	3543
Penticton	3502	Winnipeg	5871

Values for other locations . . . (see footnote bottom of page 96)

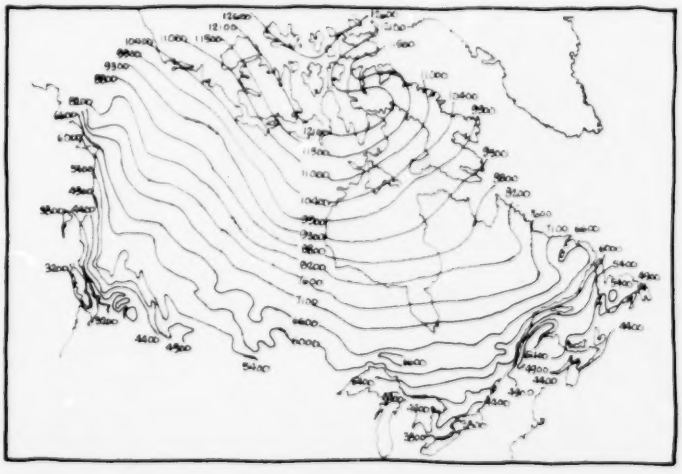


FIGURE B·1
ANNUAL DEGREE DAYS
(BELOW 18°C)

Table B.2 (from Builders' Bulletin #282, 1978-03-14)
Thermal Resistance Values of Various Building Materials[1]

Introduction

The thermal resistance of a building material or assembly is a complex property which varies with the temperature difference across the material or assembly and the mean temperature at which it is measured. The thermal resistance of air spaces is affected by these variables and also by the proportions of the space. While it may be necessary to take into account such variations when doing precise scientific calculations, such sophistication is not deemed justified for purpose of assessing compliance of housing designs with prescribed thermal resistance requirements.

The attached table provides thermal resistance values for various construction materials. These materials fall into two principal categories as follows:

- Materials which are assessed on a generic basis such as wood, concrete or bricks. The values given for this category are the only values officially recognized by CMHC.
- Materials which are assessed on a product-by-product basis. Most insulation materials fall into this category. The values given for this category are indicated by italics and are average values provided for guidance only. The values recognized by CMHC for specified products are given in CMHC's Acceptable Building Materials Systems and Equipment Manual (A.B.M.) which is available for examination at CMHC offices.

All values are given in m^2 °C/W

Thermal Resistance Values of Various Building Materials

Description	Thermal Resistance (RSI Value) For Effective Thickness	
Air Surface Films		
Still Air-Horizontal Surface-Heat Flow Up e.g. inside of ceilings	0.105	0.108[3]
Still Horizontal Surface-Heat Flow Down e.g. inside of floor	0.162	0.163[3]
Still Air-Vertical Surface-Heat Flow Horizontal e.g. inside of wall	0.120	0.121[3]
Moving Air – Any Position – outside of any surface	0.030	0.029[3]
Air Spaces – Faced with Non-reflective Materials – 12 mm Minimum Dimension		
Horizontal Space-Heat Flow Up e.g. air space in flat roof	0.150	
Horizontal Space-Heat Flow Down e.g. air space in floor	0.180	
Vertical Space-Heat Flow Horizontal e.g. air space in wall	0.171	
Air Spaces Less than 12 mm in Minimum Dimension	0	
Air Spaces – Faced with Reflective Materials[2] – 12 mm Minimum Dimension		
Horizontal Space-Faced 1 Side-Heat Flow Up e.g. air space in flat roof	0.324	
Horizontal Space-Faced 2 Side-Heat Flow Up e.g. air space in flat roof	0.332	
Horizontal Space-Faced 1 Side-Heat Flow Down e.g. air space in floor	0.980	
Horizontal Space-Faced 2 Side-Heat Flow Down e.g. air space in floor	1.034	
Vertical Space-Faced 1 Side-Heat Flow Horizontal e.g. air space in wall	0.465	
Vertical Space-Faced 2 Side-Heat Flow Horizontal e.g. air space in wall	0.480	
Air Spaces Less than 12 mm in Minimum Dimension	0	

	Thermal Resistance (RSI Value) Per mm of Thickness	
Insulation		
Mineral Wool and Glass Fibre	0.0208	0.0218[3]
Cellulose Fibre	0.0253	
Vermiculite	0.0144	0.0157[3]
Wood Fibre	0.0231	
Wood Shavings	0.0169	0.0154[3]
Expanded Polystyrene Complying with CGSB 41-GP-14a (1972)		
– TYPE 1 beadboard	0.0257	0.0267[3]
– TYPE 2 of increasing	0.0277	0.0289[3]
– TYPE 3 densities	0.0298	0.0301[3]
– TYPE 4 – extruded	0.0347	

[1] From CMHC Builders' Bulletin #282, 1978-03-14
[2] These values may not be used in calculations for areas where the mean annual total degree days exceed 4400 celsius degree days.
[3] ASHRAE Values

Table B.2 contd.

Insulation contd.	Thermal Resistance (RSI Value) Per mm of Thickness		For Thickness Listed
Rigid Glass Fibre Roof Insulation	*0.0277*		
Rigid Urethane or Isocyanurate Board	*0.0420*	0.0420[4]	
Mineral Aggregate Board	*0.0182*		
Compressed Straw Board	*0.0139*		
Fibreboard	*0.0194*	0.0183[4]	
Phenolic Foam	0.0304		
Structural Materials			
Softwood Logs and Lumber	0.0087		
Concrete			
– 2400 kg/m^3	0.00045		
– 1760 kg/m^3	0.0013		
– 480 kg/m^3	0.0069	0.0077[4]	
Concrete Block – 3 Oval Core			
Sand and Gravel Aggregate			
– 100 mm			0.125
– 200 mm			0.195
– 300 mm			0.225
Cinder Aggregate			
– 100 mm			0.195
– 200 mm			0.302
– 300 mm			0.332
Lightweight Aggregate			
– 100 mm			0.264
– 200 mm			0.352
– 300 mm			0.400
Sheathing Materials			
Softwood Plywood	0.0087		
Mat-Formed Particle Board	0.0087		
Insulating Fibreboard Sheathing	*0.0165*		
Gypsum Sheathing	0.0062		
Sheathing Paper	Negligible	0.0004/m^4	
Asphalt Coated Kraft Paper Vapour Barrier	Negligible		
Polyethylene Vapour Barrier	Negligible		
Roofing Materials			
Asphalt Roll Roofing			0.026
Asphalt Shingles			0.078
Built-up Roofing			0.058
Wood Shingles			0.165
Interior Finish Materials			
Gypsum Board. Gypsum Lath	0.0062		
Gypsum Plaster – Sand Aggregate	0.0014		
Gypsum Plaster – Lightweight Aggregate	0.0044		
Plywood	0.0087		
Hard-Pressed Fibreboard	0.0050		
Insulating Fibreboard	0.0165		
Mat-Formed Particleboard	0.0087		
Carpet and Fibrous Underlay			0.366
Carpet and Rubber Underlay			0.226
Resilient Floor Coverings			0.014
Terrazzo – 25 mm			0.014
Hardwood Flooring			
– 9.5 mm			0.060
– 19 mm			0.120
Wood Fibre Tiles			
– 13 mm			0.209

[4] ASHRAE Values

Table B.2 contd.

	Thermal Resistance (RSI Value)	
	Per mm of Thickness	For Thickness Listed
Cladding Materials		
Fibreboard Siding	0.0107	
Softwood Siding		
Drop – 18 × 184 mm		0.139
Bevel – 12 × 184 mm Lapped		0.143
Bevel – 19 × 235 mm Lapped		0.185
Plywood – 9 mm Lapped		0.103
Brick		
Clay or Shale 100 mm		0.074 0.139[5]
Concrete and Sand/Lime 100 mm		0.053
Stucco 15 mm		0.021
Metal Siding		
Horizontal Clapboard Profile		0.123
Horizontal Clapboard Profile with Backing		0.246
Vertical V-Groove Profile		0.123
Vertical Board and Batten Profile		Negligible

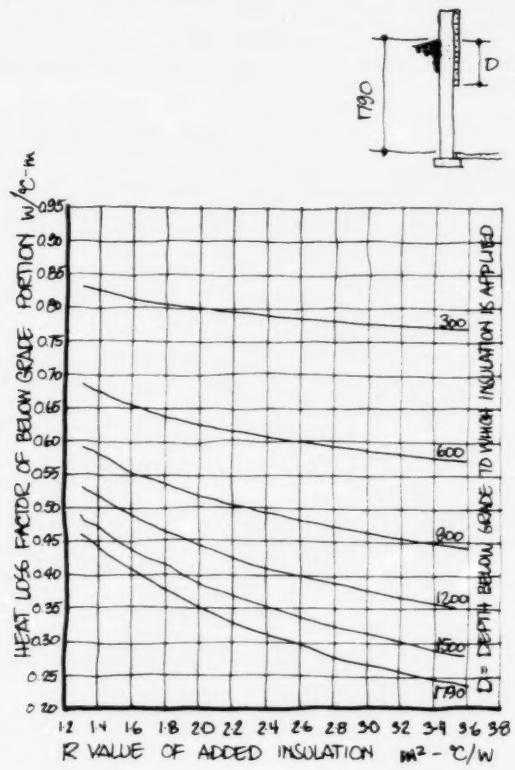


FIGURE B·2
BELOW GRADE HEAT LOSS FACTORS FOR FOUNDATION WALLS EXTENDING 1790 mm BELOW GRADE

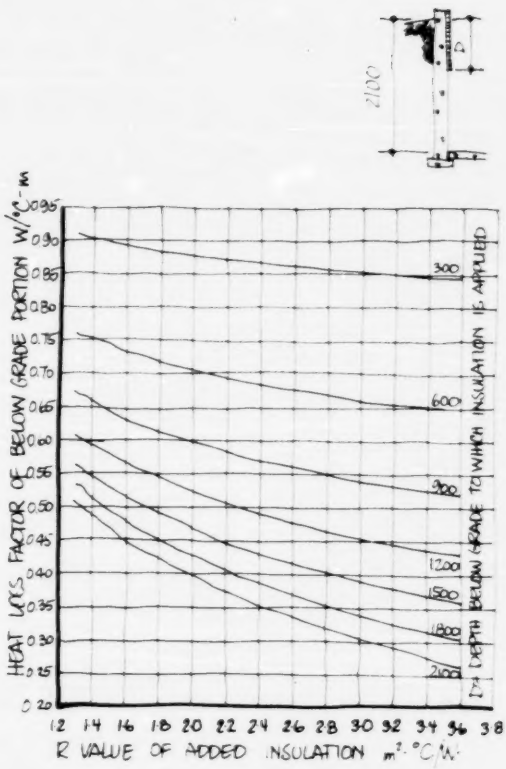


FIGURE B·3
BELOW GRADE HEAT LOSS FACTORS FOR FOUNDATION WALLS EXTENDING 2100 mm BELOW GRADE

[5] ASHRAE Values

APPENDIX C
ONTARIO BUILDING CODE REQUIREMENTS

Throughout the Guide there has been frequent reference to the Ontario Building Code (O.B.C.) which is used as a base case for many of the options examined. This appendix provides a brief summary of the relevant requirements of the latest O.B.C. in order that non-Ontario builders may have a better understanding of this base case. This Act was updated most recently in 1986 and is referred to as Ontario Regulation 419/86.

Section 9.15 Footings and Foundations

9.15.1.4

Foundations of wood frame construction are permitted to be used provided they conform to Article 9.15.1.5 or 9.15.1.6.

9.15.1.5

Except as provided in Article 9.15.1.6, wood frame foundations shall be designed in conformance with Part 4.

9.15.1.6

Wood frame foundations need not conform to Article 9.15.1.5 provided such foundations, including their lateral supports, conform to CAN3-S406, "Construction of Preserved Wood Foundations". The foundation shall be supported on soil having an allowable bearing pressure of at least 75 kPa and shall not be subjected to loads that exceed those determined from the design assumptions listed in Clause 1.1.2 of the Standard.

Section 9.19 Roof Spaces

9.19.1.5

Cross purlins required by Article 9.19.1.4. may be omitted where the roof slope is 1 in 6 or steeper provided the roof framing members run in the same direction as the roof slope and a minimum clearance of 75 mm is maintained between the underside of the roof sheathing and the top of the insulation throughout the length of the roof joist.

Section 9.22 Fireplaces

9.22.1.4

Fireplaces, including factory-built fireplaces, shall have a supply of combustion air in accordance with Article 9.22.1.5

9.22.1.5 (1)

The combustion air in Article 9.22.1.4 shall be supplied by a duct having a minimum diameter of 100 mm or equivalent area.

9.22.1.5 (2)

The air supply duct shall be non-combustible, corrosion-resistant and where exposed to room air shall be insulated for its entire length with thermal resistant insulation having a thermal resistance value of RSI 1.41.

9.22.1.5 (3)

The air supply outlet shall be located as close to the fireplace opening as possible.

9.22.1.5 (4)

When the air supply outlet is placed inside the fire chamber, it shall be located at the front centre of the chamber hearth and it shall be equipped with a non-combustible hood which when open will direct air away from the fire and shall be designed to prevent embers from entering the supply duct.

9.22.1.5 (5)

The supply duct shall contain a tight fitting damper when in the closed position and such damper shall be located close to the outlet end.

9.22.1.5 (6)

The damper shall be operable from the room containing the fireplace and the control mechanism shall clearly indicate the actual position of the damper.

9.22.1.5 (7)

The air supply duct shall be installed with a minimum 50 mm clearance from combustibles for 1 m distance measured away from any outlet located in the fire chamber.

9.22.1.5 (8)

The exterior air supply inlet duct shall be protected against the entry of rain and direct wind. The inlet opening shall have an insect screen of corrosion-resistant material.

9.22.1.5 (9)

The exterior air duct inlet shall be located to avoid being blocked by either snow or fallen leaves.

Section 9.26 Thermal Insulation and Vapour Barriers

9.26.2.5

Insulation around concrete slabs-on-ground shall extend not less than 600 mm below exterior ground level.

9.26.2.6 (1)

Except for doors, windows, skylights and other openings the thermal resistance of insulation shall conform to Table 9.26.2.A

9.26.2.6 (2)

Every foundation wall face having more than 50 per cent of its area exposed to outside air and those parts of foundation walls made of wood-frame construction above exterior ground level shall have a thermal resistance rating conforming to the requirements for exposed walls in Table 9.26.2.A.

Table 9.39.3
Minimum Thermal Resistance of Insulation to be Installed for all Degree Day Zones

Construction	RSI-Value Required
Exposed ceiling	5.40
Exposed roof	3 52
Exposed walls	2 11
Foundation walls - solid	1 41
- frame	2 11
Exposed floors	4.40
Slabs on grade - unheated	1 41
- heated	1 76

9.26.2.6 (3)

The thermal resistance values in Table 9.26.2.A. for exposed roofs or ceilings may be reduced near eaves to the extent made necessary by the roof slope and required ventilation clearances, except that the thermal resistance of insulation at the location directly above the inner surface of the exterior wall shall be at least RSI 2.1.

9.26.3.2

Type I expanded polystyrene insulation as described in C.G.S.B. 51-6P-20M, "Thermal Insulation, Expanded Polystryene", shall not be used in contact with the ground or as roof insulation applied about the roofing membrane.

9.26.4.3

Batt-type insulation manufactured with no membrane on either face shall be installed so that at least 1 face is in full and continuous contact with cladding, sheathing or other membrane.

9.26.4.10

Where insulation is exposed to the weather and subject to mechanical damage, it shall be protected with not less than 6 mm asbestos-cement board, or 12 mm cement parging on wire lath applied to the exposed face.

9.26.4.13 (1)

The upper part of foundation walls enclosing heated space shall be insulated from the underside of the subfloor to not less than 600 mm below the finished ground level.

9.26.4.13 (2)

If a foundation wall is constructed of hollow masonry units, one or more of the following shall be used to control convection currents in the core spaces,

(a) filling the core spaces,
(b) at least one row of semi-solid blocks at or below grade, or
(c) other similar methods.

9.26.4.14 (1)

Insulation for the below-grade portion of the interior of foundation walls shall be protected from moisture by a moisture barrier, or the insulation is to be inherently moisture resistant and batt-type insulation shall be additionally protected by a vapour barrier.

9.26.4.14 (2)

Insulation on the inside of such foundation walls shall be installed tightly against the foundation wall and shall be sealed at the top and at the bottom to reduce air circulation.

9.26.5.4

Insulation shall be protected by a vapour barrier installed so that all joints are lapped at least 100 mm.

9.26.5.7

Holes through vapour barriers, such as those cut for the installation of electrical wiring, electrical boxes, piping or ductwork, shall be sealed to maintain the integrity of the vapour barrier over trhe entire surface.

9.26.5.8

Access hatches into attics shall be weather stripped around the perimeter of the hatches.

9.26.5.10

Clearances between chimneys or gas vents and the surrounding construction which would permit air leakage from within the building into an attic or roof space shall be sealed by noncombustible material to prevent such leakage.

9.26.5.11

Masonry walls of hollow units which penetrate through the ceiling shall be capped with masonry units without voids or be sealed with flashing material extending across the full width of the masonry at or near the ceiling adjacent to the roof space to prevent moisture within the voids from entering the attic or roof space.

Section 9.39 Thermal Design

9.39.4.1

Except as provided in Articles 9.39.4.2 and 9.39.4 4, all glazing that separates heated space from unheated space or the exterior shall have a thermal resistance of at least 0.30 m^2 °C/W.

9.39.4.3

Except as provided in Articles 9.39.4.4 and 9.39.4.5, the total area of glazing, including glazing for doors and skylights, that separates heated space from unheated space or the exterior shall not exceed 20 per cent of the floor area of the storey served by the glazed areas and shall not exceed 40 per cent of the total area of the walls of that storey separating heated space from unheated space or the exterior.

9.39.7.1

Fresh air for the ventilation of rooms and spaces in buildings of residential occupancy shall be provided at a rate of at least 0.5 air change per hour by a combination of natural and mechanical ventilation.

APPENDIX D
COMPARISON OF INSULATION OPTIONS WITH "MEASURES FOR ENERGY CONSERVATION IN NEW BUILDINGS"

"Measures for Energy Conservation in New Buildings" was originally published in 1978 and has been updated with a new edition in 1983 by the Associate Committee on the National Building Code. Like the National Building Code, it is a model document with no force unless adopted by an authority such as a municipality, a province, or Canada Mortgage and Housing Corporation. At time of publication of the Guide, no such authority had adopted the "Measures" but it seemed likely that it would eventually be adopted by at least some authorities. This appendix is provided, therefore, to assist builders who may be required to comply with the "Measures".

Figures D.1 to D.5 show the relationship between Ontario Building Code minimums and the minimum RSI Values included in the "Measures".

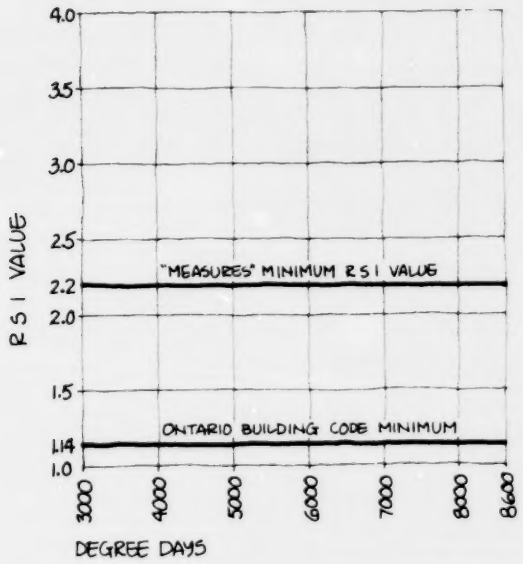


FIGURE D-1 MINIMUM THERMAL RESISTANCE OF FOUNDATION INSULATION (SOLID) — COMPARISON BETWEEN "MEASURES" & THE ONTARIO BUILDING CODE NOV. 1983

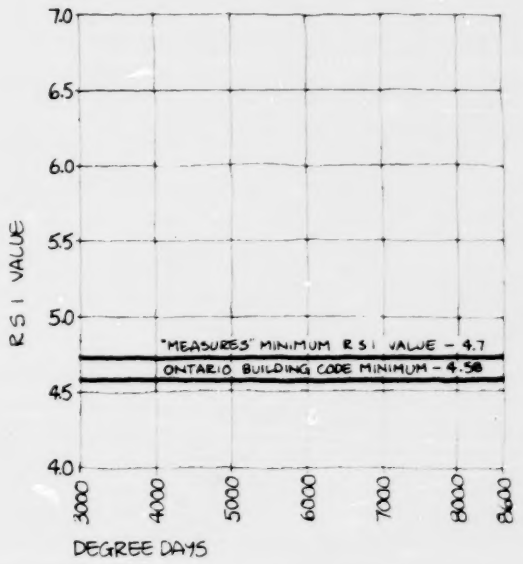


FIGURE D-2 MINIMUM THERMAL RESISTANCE OF FLOOR INSULATION (EXPOSED) — COMPARISON BETWEEN "MEASURES" & THE ONTARIO BUILDING CODE NOV. 1983

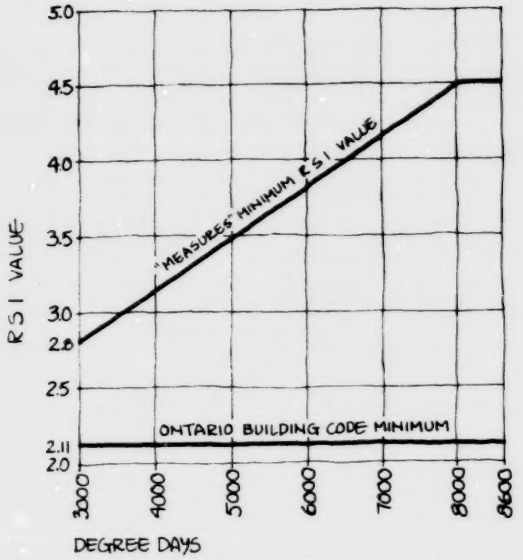


FIGURE D-3 MINIMUM THERMAL RESISTANCE OF WALL INSULATION — COMPARISON BETWEEN "MEASURES" & THE ONTARIO BUILDING CODE NOV. 1983

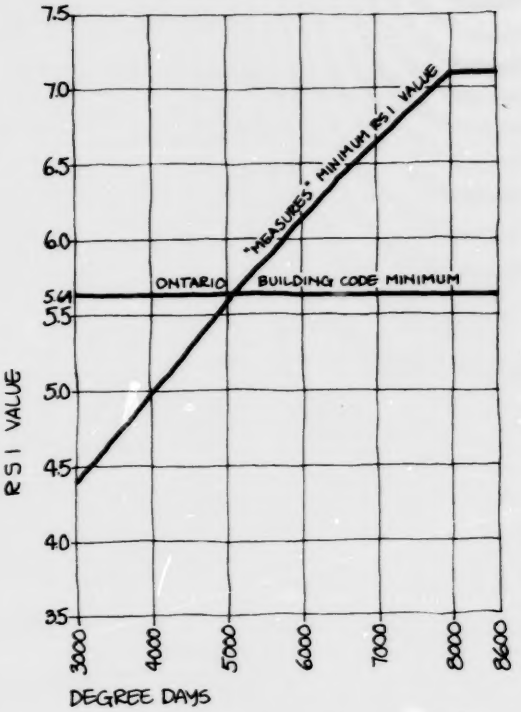


FIGURE D-4 MINIMUM THERMAL RESISTANCE OF ATTIC-TYPE ROOF INSULATION COMPARISON BETWEEN "MEASURES" & THE ONTARIO BUILDING CODE NOV. 1983

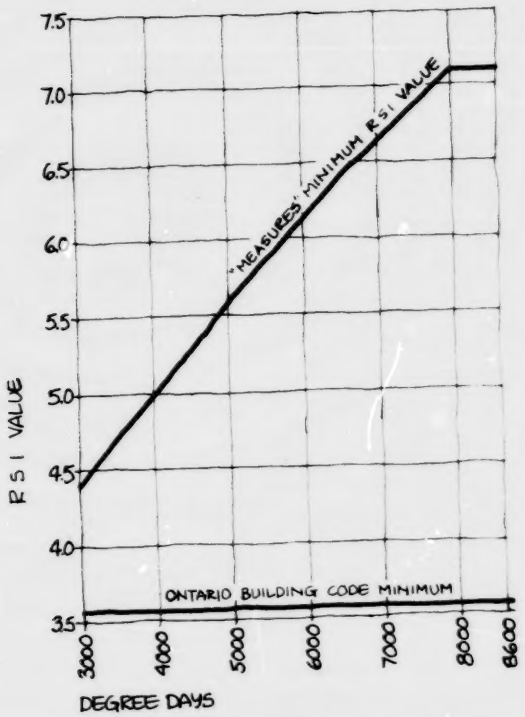


FIGURE D-5 MINIMUM THERMAL RESISTANCE OF FLAT OR CATHEDRAL ROOF INSULATION — COMPARISON BETWEEN "MEASURES" & THE ONTARIO BUILDING CODE NOV. 1983

APPENDIX E
HOT 2000: A COMPUTER PROGRAM FOR ESTIMATING THE SPACE HEATING REQUIREMENTS OF RESIDENCES

Originally developed for the R-2000 super energy efficient home program (SEEH), Hot 2000 is the latest version of a user friendly computer program that is able to calculate the annual energy requirements of a house design.

However, Hot 2000 is more than a simple energy calculation program. Once the data on a house is entered into the program, Hot 2000 can be used as a design tool. Certain characateristics of the house can be changed to determine the impact on the amount and type of energy used. For example, you could compare the cost of using a natural gas furnace versus a heat pump. Some other examples of the kind of questions that Hot 2000 can answer include:

- What happens to the energy consumption of a house if a large sun space is added to the south side of the building?
- How much energy and money would be saved by incorporating a Heat Recovery Ventilator (HRV) into the mechanical ventilation system for a house? Is the extra expenditure worth the savings?
- In insulating a building is it more cost effective to add extra insulation to the attic or should more energy efficient windows be considered.
- Will a design meet the energy consumption targets set out by the R-2000 program? What are the changes necessay to bring a design up to R-2000 standards?
- Which fuel is more economical to use for heating: propane, oil or wood. If the furnace used is high efficiency, how are costs affected.

Below is an example of a Hot 2000 data sheet that details the information required to run your design on the Hot 2000 program.

If you would like to order your own copy of the Hot 2000 computer program, the cost is $95.00. It can be ordered from :

Hot 2000
R-2000 Energy Analysis Program
P.O. Box 7081
Postal Station J
Ottawa, Ontario
K2A 3Z2
(613) 722-5091

HOTCAN Building Data Sheet

1. **Location** _____ **Date** _____
2. **Name** _____ **Address** _____

   Tel. No. ( ) _____ _____
3. **File Name & Run No.** _____ a) Complete or Simplified Inputs _____
   b) Main Living Area Design Temp. _____
4. **Degree Days C°** _____ c) Basement Area _____
5. a) **Fuel used for Space Heating** _____ (fuel) @ _____ ¢ per _____
   b) **Fuel used for Domestic Hot Water Heating** _____ (fuel) @ _____ ¢ per _____
6. **Mass Level in House**
   a) Wood Frame Construction, 12.7 mm gypsum board walls and ceilings, carpet over wood floor.
   b) As 'a' except, 50.8 mm gypsum board walls and 25.4 mm gypsum board ceiling.
   c) Interior wall finish of 101.6 mm brick, 12.7 mm gypsum board ceiling, carpet over wood floor.
   d) Very hard commercial office building, 305 mm concrete floor.

		Area sq. m/sq. ft.	Total Sectional RSI/R
7.	**Imperial or Metric Inputs** _____		
8.	**Insulated Ceiling Area**		
	a) 1st floor		
	b) 2nd floor		
	c) Other		
9.	**Insulated Exterior Wall Area**		
	a) 1st floor Net (less doors & windows)		
	b) 2nd floor Net (less doors & windows)		
	c) Common Wall Area of House & Garage		
	d) Floor Header Areas		
	e) Cantilevered Floor Area		
	f) Other		
10.	**Doors**		
	Net Area (less glazing)		
11.	**Basement Walls Above Grade**		
	Net Area (less doors & windows)		
12.	**Basement Walls from Grade to .6m Below Grade**		
	Net Area (less doors & windows)		
13.	**Basement Walls from .6m Below Grade to Floor**		
	Net Area (less doors & windows)		
14.	**Basement Floor Area 1 Meter Perimeter**		
15.	**Basement Floor Centre Area**		
16.	**Is Basement Insulated Mainly on Inside or Outside?**		

HOTCAN Building Data Sheet

17. **Do any of the Windows have Shutters?** **Yes or No** _____

    If **Yes,** what is the RSI/R value? _____

18. **Glass Pane Thickness?** 3 mm or 6 mm _____

19. **South Windows**

Area (sq. ft./m^2)	____	____	____	____	____	____	____	____	____
No. of Glazings	____	____	____	____	____	____	____	____	____
RSI/R or Spacing	____	____	____	____	____	____	____	____	____
Window Height	____	____	____	____	____	____	____	____	____
Overhang Width	____	____	____	____	____	____	____	____	____
Height above Windows	____	____	____	____	____	____	____	____	____

20. **Shading Co-Efficient** (if known) _____

21. **North Windows**

Area _____ No. of Glazings _____ Space Between Glazing _____ Glass Thickness ____ Shutters _____

22. **East Windows**

Area _____ No. of Glazings _____ Space Between Glazing _____ Glass Thickness ____ Shutters _____

23. **West Windows**

Area _____ No. of Glazings _____ Space Between Glazing _____ Glass Thickness ____ Shutters _____

24. **House Volume** _____ m^3/cu. ft.

25. **Air Changes** (Natural) _____ / hr.

26. **Air Changes** (Mechanical) _____ / hr.

27. **Heat Recovery on Air Changes?** Yes or No _____

28. **Number of Occupants Expected to Occupy the House** _____

29. **Other House Features That May Affect Heat Loss** e.g. Fireplace, slab on grade, etc.
    Please give complete details as to **Size, Location, Characteristics, R Value, Cross Section** details, etc.

Appendix F
ORF Spec Sheets

HRV DESIGN SPECIFICATION SHEET

EXAMPLE ONLY

Date Tested: _____
Manufacturer: _____
Address: _____

Tel: _____

Model: The Blowhard
Serial Number: _____
Options Installed: _____

Electrical Requirements: ____Volts ____Amps

VENTILATION PERFORMANCE

External Static Pressure		Net Supply Air Flow		Gross Air Flow Supply		Gross Air Flow Exhaust		Effective Duct Length Supply	Effective Duct Length Exhaust
Pa	in.W.G.	L/s	cfm	L/s	cfm	L/s	cfm	Feet	Feet
25	0.1								
50	0.2		260		265		295	40	35
75	0.3		243		250		275	70	60
100	0.4		221		225		250	108	90
125	0.5		196		200		230	162	135
150	0.6		176		180		210	244	195
175	0.7		157		165		180	386	300
200	0.8		120		125		150	707	490
225	0.9		71		75		100	1600	900

Exhaust Air Transfer Ratio 2.5 @100 Pa 2.5 @50 Pa
Low Temperature Reduction Factor 15 % Supply 24 % Exhaust
Low Temperature Imbalance Factor 1.03

Duct Diameter
Exhaust 6 in.
Supply 6 in.

ENERGY PERFORMANCE

cooling heating

Supply Temperature °C	Supply Temperature °F	Net Air Flow L/s	Net Air Flow cfm	Average Power (Watts)	Sensible Recovery Efficiency	Apparent Sensible Effectiveness	Net Moisture Transfer
0	32		275	235	45	58	0
0	32		230	220	50	60	0
0	32		135	95	64	78	0
0	32		120		66		
-25	-13		0	85	60	72	0
-25	-13		0		60		
35	95		0				
35	95		0				

Description of Defrost:

Comments from Test Agency:

How To Read The HRV Design Specification Sheet

This section explains what the terms on the HRV design sheet mean and how to use the sheet when you are considering purchasing an HRV. A more technical explination of terms can be found on the reverse side of each design specification sheet.

Ventilation Performance Section

2 External Static Pressure

When ductwork is attached to an HRV, air flow through the duct will be reduced because of the frictional resistance of the duct walls. External Static Pressure represents this resistance to airflow

3 Net Supply Air Flow

This column provides information on the air flows that can be provided by the HRV at different External Static Pressures. In selecting an HRV, you should be sure that the air flow ratings are equal to or greater than the design airflow capacity required for the house.

4 Gross Air Flow

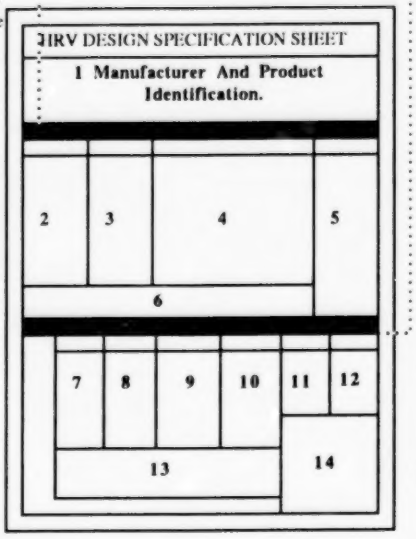
The figures in these columns are used by the duct designer to determine the best size of ducting to use.

5 Effective Duct Length

This column indicates the maximum amount of straight duct that can be connected to the HRV to provide various airflows. This information is useful for comparing the airflow performance of various HRV's. However, when comparing units make sure that the duct size noted at the bottom of the column is the same for units being compared.

6 Cross Leakage, And The Effect Of Low Temperatures On Airflow And Balancing Of The System

This section is explained in greater technical detail on the back of the HRV Design Specification Sheet.



Energy Performance Section

7 Supply Temperatures

This provides information on the various temperatures the HRV was tested at. At -25° all results in the Energy Performance Section represent the average measurement during the last 12 hours of 3 days of continious operation.

8 Net Air Flows

Indicates the different air flow conditions that the Unit was tested under.

9 Average Power (Watts)

Indicates the power consumption of the HRV under different air flow and temperature conditions. This includes power consumption for fans, controls and defrost mechinism.

10 Sensible Recovery Efficiency

The performance rating for the HRV under different air flow and temperature conditions. The performance of HRV's should be compared using these figures.

11 Apparent Sensible Effectiveness

Used primarly by designers to predict the pre-warmed temperature of incoming fresh air.

12 Net Moisture Transfer

Indicates the percentage of moisture or humidity that is transferred between the exhaust and supply air streams.

13 Description Of Type Of Defrost

14 Comments By Test Agency

Appendix G
ABBREVIATIONS AND CONVERSION FACTORS

°C degrees celsius

DD: degree days (The annual total degree days is the sum of the differences between 18°C and the mean temperatures in °C of every day in the year when the mean temperature is below 18°C)

F.F.: friction fit

G: overall heat loss factor for the dwelling expressed in MJ/hr.–°C or W/°C

GJ: gigajoule (1 gigajoule = 1,000 megajoules)

H.L.F.: annual heat loss factor expressed in watts per degree celsius per metre = W/°C-m

J: joule

kg: kilogram (1 kilogram = 2.2 pounds)

kWh: kilowatt-hour (1 kWh = 3.6 MJ = 3,413 British Thermal Units)

L: litre (1L = 0.0253 cubic feet, 1L = 0.220 imperial gallons)

MJ: megajoule (1MJ = 1,000,000 J = 947.8 British Thermal Units)

m^2: square metres ($1m^2$ = 10.76 square feet)

m^3: cubic metres ($1m^3$ = 35.314 cubic feet = 1,000 litres)

min: minimum

Pa: Pascal (1 Pascal = 1 Newton per square metre = 145.03 pounds per square foot)

P.B.: paper backed

RSI: resistance to heat flow, expressed as m^2 °C – W (in metric units)

RSI: = 0.176 R (resistance in imperial units)

W: watt (1 watt = 1 joule/second)

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers

CHVAC: Canadian Heating, Ventilating and Air Conditioning Code

CMHC: Canada Mortgage and Housing Corporation

CSA: Canadian Standards Association

HRAI: Heating Refrigerating and Air-Conditioning Institute

ULC: Underwriter's Laboratories of Canada

1L of #2 fuel oil provides a heating value = 38 MJ

$1m^3$ of natural gas provides a heating value = 37 MJ

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